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Vienna (Ottakring), Austria, Von Kuffnersche Sternwarte.
Washington, District of Columbia, Library of Congress, Periodical Division.
Washington, District of Columbia, National Academy of Sciences.
Washington, District of Columbia, Naval Observatory.
Washington, District of Columbia, Smithsonian Institution.
Washington, District of Columbia, The American Ephemeris.
Washington, District of Columbia, U. S. Coast and Geodetic Survey.
Williams Bay, Wisconsin, Yerkes Observatory.
Zurich, Switzerland, Observatory.

EXCHANGES.

Astrophysical Journal, Williams Bay, Wisconsin.
Popular Astronomy, Northfield, Minn.
Prof. Dr. H. J. Klein, Editor of *Sirius,* Theresien St. 85, Köln-Lindenthal, Germany.
The Observatory, Greenwich, England.

FOR REVIEW.

[See *Publications* A. S. P., Vol. VIII, p. 101.]

The Call, San Francisco, California.
The Chronicle, San Francisco, California.
The Examiner, San Francisco, California.
The Mercury, San Jose, California.
The Record-Union, Sacramento, California.
The Times, Los Angeles, California.
The Tribune, Oakland, California.

METHODS OF MEASUREMENT AND REDUCTION OF SPECTROGRAMS FOR THE DETERMINATION OF RADIAL VELOCITIES.

By J. H. Moore.

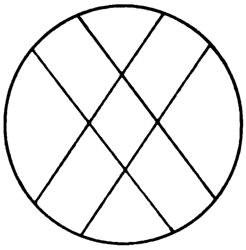
There is probably no field of astronomy in which the development of instruments and methods has been so rapid as in the application of the spectroscope to the determination of the radial velocities of stars according to the Doppler-Fizeau principle. In the first investigations made by Huggins in 1867, and by Vogel in 1872, the observations were visual, and it was not unusual to obtain discrepancies in the results amounting to as much as the quantities to be measured. Observations of value date from the application, by Vogel in 1887, of the photographic method to this problem, a method which had already achieved remarkable results in the hands of Professor Pickering in his qualitative studies of stellar spectra. Following this and the subsequent improvement in design of spectrographs and methods of reduction in which Professor Campbell at the Lick Observatory led the way, there has been a continual development in the instrumental and observational side giving spectrograms of greater accuracy. At the same time refinements have been introduced into the methods of measuring and reducing these spectrograms in order to obtain from them velocities as accurate as the plates will warrant. It will be the purpose of the present article to outline the various methods which have been used for the measurement and reduction of spectrograms for radial velocity determinations and to discuss the advantages and limitations of each.

A stellar spectrogram for this purpose consists of a star spectrum and a comparison spectrum produced by a known source, such as the metallic arc, spark, or vacuum-tube discharge. The light from the star and the artificial source are made to pass over equivalent optical paths in the spectrograph and the spectra of the two brought to a focus on the photographic plate in such a way that the star spectrum falls in the center and the comparison spectrum on each side of it. In most astronomical spectrographs of high dispersion only a

comparatively short section of the spectrum (about three or four hundred tenth-meters) is in sharp focus. With these instruments we utilize only the part of the spectrum to which the photographic plate is extremely sensitive. Fortunately this region is as rich in lines as any other part of the spectrum, and is about the one of maximum dispersion of glass prisms consistent with permissible loss of light by absorption. In some spectrographs the prisms are set at minimum deviation for λ 4340, in others at λ 4500, or for some point intermediate between these wave-lengths. The measurable spectrum extends from about λ 4230 to λ 4490 in the first case, and from about λ 4340 to λ 4630 in the second case. For comparison spectrum a metal is chosen which is rich in lines for the region used. For example, iron is generally chosen for the former, while titanium and vanadium are employed for the latter region. The positions on the plate of the lines in the star spectrum (*i. e.* their wave-lengths) are, according to the Doppler-Fizeau principle, affected by the relative velocity of the star and the observer in the line of sight, while the wave-lengths of the comparison lines are unaffected by such velocity, their source being on the instrument. The radial velocity of the star is determined by measurement of the relative positions of the lines in the two spectra.

MEASUREMENT OF PLATES.

Most line-of-sight observers have employed for the measurement of spectrograms either the Töpfer engine, or the one designed by Professors HALE and FROST and made by GAERTNER. It is necessary first to test for the errors of the screw, and if they are comparable with the error of setting on lines of the spectrum they must be taken into account. Most observers use one vertical wire for making the settings. The accuracy of settings on strong comparison lines is increased, according to FROST, by the use of two parallel vertical wires, but such a form is seldom used. A reticle of the form shown in the figure, sometimes used in the measure of grating plates, possesses points of advantage over either of the other forms.



The method of measuring a plate varies somewhat with

different observers, but, with the exception of the use of the Hartmann spectrocomparator, is briefly as follows: The plate is placed on the engine (usually with violet apparently left), properly aligned, and so adjusted that the reading on a selected comparison line shall be some arbitrary one agreeing with the standard table to be used for reduction. Settings are made continuously along the plate on good star and comparison lines as they chance to occur. The plate is then reversed and the settings repeated, the plate being so adjusted, for convenience, that the reading on the first comparison line in the second position shall equal a constant (say 100) minus the reading on the same line in the first position. The effect of errors due to personal equation is, according to the investigations of Professor LORD and Professor BELOPOLSKY and the more exhaustive ones of Dr. REESE,[1] practically eliminated by taking the mean of the measures of the plate in the two positions. It should be noticed, however, that in the reversal of the plate the spectrum is also inverted, which might so change the appearance of lines as to interfere with the elimination of personal equation in this way. Curvature of the spectrum lines may also interfere in like manner with the elimination of this source of error. The effect of accidental errors in setting on lines is reduced by employing a number of lines. Care should be taken to maintain the engine at as nearly a constant temperature as possible, and especially to keep the illumination of the plate the same during the entire measure.

METHODS OF REDUCTION.

Professor VOGEL in his early work used only the $H\gamma$ line for comparison, and measured the displacement between the $H\gamma$ of the star spectrum and that of the vacuum tube. Later, for stars of the solar type he employed the iron spectrum for comparison, and measured the displacement between the iron lines in the star and comparison spectra. This gave only about eight or ten independent measures of the displacement, so that in the case of stars rich in lines, as those of the F to M types, he was using only a very small part of the material on each plate and not making the best possible selection of lines. Methods have been devised, however, which enable us to use other lines in the star spectrum than those corresponding

[1] *L. O. Bulletin* No. 15, and *Astrophysical Journal*, Vol. 15, 208, 1902.

to the comparison spectrum. These may be grouped under the following heads: I. Methods of interpolation by dispersion formulæ; II. The velocity standard method; III. The spectro-comparator method.

I. *Methods of Interpolation.*—Methods of interpolation were introduced by Professor CAMPBELL in 1896 (not published until 1898[1]) and by Professor HARTMANN in 1898,[2] which made it possible to use all the stellar lines on the plate, provided their wave-lengths are known. This is accomplished by the aid of a table of micrometer settings corresponding to the wave-lengths of the lines employed. The relation between wave-length and the corresponding micrometer setting is expressed by means of a dispersion formula, the constants of which are determined from the measures of lines of known wave-length in a spectrum of a source whose radial velocity is approximately zero,—for example, the Sun.

In explaining this method we shall first assume that it is possible to obtain a formula which shall accurately represent the relation existing between wave-lengths and micrometer readings for the whole region of spectrum to be used, and that such a table has been formed from our Sun plate, leaving to a later paragraph the discussion of the formulæ actually used by CAMPBELL and by HARTMANN.

λ	Sun.	rV_s'
4338.084	10.258	299
4340.634	10.846	300
⋮	⋮	⋮
4351.930	13.433	304
⋮	⋮	⋮
4501.448	43.723	367
⋮	⋮	⋮
4656.644	69.215	434

We have, then, a table we shall call our standard dispersion table. In the first column under λ are given the wave-lengths of the lines of the Sun taken from ROWLAND'S Preliminary Table of Solar Wave-Lengths. The second column contains the micrometer readings corresponding to the wave-lengths of the first column. These settings are computed from the constants of the Sun plate. The third column contains the values of rV_s', the factor for each line by which the displacement is multiplied in order to obtain the corresponding velocity in kilometers per second; V_s', the velocity in kilometers per second corresponding

[1] *Astrophysical Journal*, Vol. 8, 123, 1898.

[2] *Astrophysical Journal*, Vol. 8, 218, 1898; *Astronomische Nachrichten*, Vol. 155, 81-118, 1901.

to a displacement of one tenth-meter $= \frac{\text{velocity of light}}{\text{wave-length}} = \frac{299860}{\lambda}$. The quantity r, the number of tenth-meters in one revolution of the screw, is obtained from the original constants of the dispersion formula. Its value will be deduced later.

In measuring the star plate, set it so that one of the comparison lines—say 4338.084—has the tabular micrometer reading 10.258, and make the settings on the other comparison and star lines as described above. Take the difference, micrometer reading of comparison line on star plate minus micrometer reading of same comparison line in our table (under Sun). Next plot a curve with wave-lengths as abscissæ, and these differences as ordinates. Construct a table of micrometer settings (for zero velocity) for star lines measured on the plate by applying to the tabulated settings for these lines corrections read off from the curve. Suppose, for example, we wish to obtain the reading for the line 4351.930 on a star plate (*i. e.* the reading which this star line would have if unshifted by radial velocity). We read off from the curve the difference corresponding to λ 4351.930 and add it to the micrometer reading 13.433 in the table. Suppose it is $+ .022$. Then the reading for zero velocity would be 13.455, and if the micrometer setting of this line on the star plate is 13.330, then the displacement is $-.135$. Where there are comparison lines corresponding to star lines some observers take the difference between the micrometer readings directly for the displacements, while others rigorously follow the process just outlined. Having now the displacements for each of the stellar lines measured it is necessary to multiply each one by the corresponding rV_s in order to obtain the velocity. The mean of the velocities obtained from the different lines, which we may call v_s, is the relative velocity of the star and observer in the line of sight. It is necessary to apply two small corrections to v_s; a correction for scale and a correction for curvature of the spectrum lines. If the dispersion of the star plate differs greatly from that of the dispersion table, the values of r in the table will be too large or small for the star plate. In place of computing the r for each line we apply a correction to v_s, obtained as follows: Let a be the difference between the tabular micrometer readings

of the first and last comparison lines used, and b the difference in the actual settings on the plate for these same comparison lines, then the correction for scale $= \frac{a-b}{a} v_s$. It has the same sign as v_s if $a > b$ and opposite if $a < b$. The correction for curvature of the spectral lines may be computed by DITSCHEINER's formula,[1] which has been found by ADAMS[2] to be accurate for long slits. Some observers determined this correction empirically from lines in the solar spectrum on the assumption that the curve is a parabola. The effect of curvature is eliminated in the new Mills spectrograph by using a curved slit which gives straight spectral lines.

In order to reduce this value of the radial velocity to the Sun, the corrections for the annual and diurnal motions of the Earth are computed from the formulæ given by Professor CAMPBELL in FROST-SCHEINER, pp. 338-345.[3] If v_a be the correction to the observed velocity of the star for the Earth's annual motion, then

$$v_a = -V'_a \sin(\lambda - \odot + i) \cos \beta$$

where V'_a = the Earth's velocity in kilometers per second in its orbit;

λ and β = the longitude and latitude of the star observed;

$\odot$ = the Sun's longitude at the time of observation;

$90° - i$ = the angle which the tangent to the Earth's orbit makes with the radius-vector drawn to the point of tangency.

The correction v_d due to the diurnal rotation of the Earth is given by

$$v_d = -V'_d \sin t \cos \delta \cos \phi.$$

where V'_d = the velocity in kilometers per second of a point on the Earth's equator due to the diurnal rotation, and equals 0.47;

t = the hour angle of the star observed;

δ = the declination of the star observed;

ϕ = the latitude of the observer.

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[1] For this formula and its derivation see FROST-SCHEINER, p. 15; also, see an article by Professor LORD, *Astrophysical Journal*, Vol. 5, 348, 1897.

[2] *Astrophysical Journal*, Vol. 11, 309, 1900.

[3] See Professor SCHLESINGER's article in *Astrophysical Journal*, Vol. 10, 1-13, 1899; also an approximate method for reductions to the Sun by Dr. PALMER in *L. O. Bulletin* No. 98, 1906; and a recent graphical method proposed by HARTMANN in *Astronomische Nachrichten*, Vol. 173, 97, 1906.

The reduction is simplified by the use of tables giving V'_a and i for different values of $\odot$. and a table giving V'_d for different hour angles and declinations. The value of the lunar correction is small and is usually neglected. It may amount at maximum to about .01 kilometer.

Dispersion Formulæ.—In order to determine the relation existing between wave-lengths and micrometer readings CAMPBELL[1] measured the positions of twenty-two selected lines on a plate of the solar spectrum made with the Mills spectrograph. Taking wave-lengths as abscissæ and micrometer readings as ordinates, he assumed the origin of abscissæ at λ 4330 (*i. e.* a point near the middle of the plate) and the origin of ordinates at micrometer readings 32.000 corresponding to λ 4330. If x is the difference in wave-length in tenth-meters between any line and λ 4330, he assumed that the micrometer reading of a line whose wave-length was λ $(4330 + x)$ was given by $R = 32.000 + a + bx + cx^2 + dx^3$. From the twenty-two lines as many equations resulted for the determination of the constants a, b, c, and d, which were solved by the method of least squares. The agreement between the computed and observed micrometer readings was found to be satisfactory not only for the above lines but for intermediate lines as well, throughout the whole region of spectrum employed by him (λ 4238 to λ 4442). In order to obtain the value of r in the expression rV'_t, he obtained by differentiating the above formula $\frac{dx}{dR} = \frac{1}{b + 2cx + 3dx^2}$ Taking dR equal to unity dx becomes the number of tenth-meters in one revolution of the screw (*i. e.*, $r = dx$). The wave-lengths used were taken from ROWLAND'S table of solar wave-lengths, and the assumption was made that the wave-lengths of the iron comparison lines used were the same as those of the corresponding iron lines in the solar spectrum. The main objection to the use of the above formula is the great amount of labor involved in making the solution for the constants, in order that the curve should represent accurately the region of spectrum employed.

Professor HARTMANN[2] proposed a dispersion formula which

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[1] *l. c.*, p. 142.

[2] This is generally known as the Cornu-Hartmann dispersion formula. The form in which it was originally given by CORNU was with the exponent $a = 1$. The formula was arrived at, however, independently by HARTMANN, by plotting the

is quite simple and gives a curve which will represent with sufficient accuracy a long section of the spectrum. If x be the micrometer reading corresponding to the wave-length λ, then $x - x_0 = \frac{c}{(\lambda - \lambda_0)^a}$ where x_0, λ_0, c, and a are constants to be determined by observation. λ_0 and a characterize the general form of the dispersion curve and are for the same spectrograph nearly constant; c is the screw value, and is affected directly by a change in dispersion with temperature; x_0 is an additive constant which depends upon the position the plate is initially given on the measuring-engine. He determined the constant a in the following manner. Settings were made on five lines in different parts of a spectrogram of the Sun. Assuming $a = 1$, he computed from the two end lines and the middle line the values of the other constants. The residuals from the observed minus the computed micrometer readings on the other two lines were of opposite sign. An assumption of $a = 0.9$ gave smaller residuals for these two lines. From the residuals obtained, using these two values of a, it was evident that the correct value of a was about 0.6. Using this value of a, he then computed the micrometer settings for the other lines which he wished to use and found that this dispersion curve represented the observed settings within the errors of observation for the region λ 4220 to λ 4680. Beyond these points it runs off rapidly. HARTMANN computes, from plates made at different temperatures, tables for every 4° difference in temperature of the spectrograph, and uses the table nearest to the dispersion of the star plate for the reduction. With this method of procedure the correction for scale is practically negligible. The value of r is obtained by differentiation of the original formula and its value is given by $\frac{(\lambda - \lambda_0)^{1+a}}{a\,c}$ where the same constants are taken as in the original computation.

Most line-of-sight observers have adopted the Cornu-Hartmann dispersion formula for the reduction of their spectrograms, although the details of the reductions vary. In the computation of the dispersion table for the new Mills spectro-

refractive index of quartz for different wave-lengths. This curve is an equilateral hyperbola which could be represented by an equation of the above form. See Potsdam *Publications*, Vol. XII.

graph we used the formula with $a = 1$, divided the spectrum from λ 4340 to λ 4630 into three sections, and computed a set of constants from three lines for each section. The continuity of the curve was assured by taking the last lines of the first and second sections as the first lines respectively of the second and third sections. The representation of the observations was found to be satisfactory. The dispersion table of the Southern Mills spectrograph was computed, placing $a = 1$, from only three lines for the whole region. The residual differences from the observed values, when plotted against the wave-lengths as abscissæ, gave an S-shaped curve from which corrections to the computed values were read off.

Professor FROST[1] prefers to reduce each of his plates independently of any other plate; *i. e.* he computes a dispersion table for each plate. Three lines of the comparison spectrum chosen for their sharpness and for their proper spacing (one near each end and one near the middle of the spectrum) give the values of the constants λ_0, x_0, and c in the Cornu-Hartmann formula where $a = 1$. He then computes the wave-lengths of the comparison and star lines measured. The differences between the computed values of the wave-lengths of the comparison lines and those given for the same lines in ROWLAND's tables of solar wave-lengths are taken as "corrections to comparison lines." These, aside from the accidental errors of setting, he takes as representing the departure of the formula from an exact representation of the wave-lengths. The corrections for the star lines are interpolated from the corrections for the adjacent comparison lines. He prefers to do this rather than to draw a smooth curve for the corrections to the comparison lines, fearing the arbitrary smoothing out of such a curve more than the accidental errors of settings and the more serious effects of errors in wave-length of the comparison lines.

Methods of reduction which depend upon dispersion formulæ require an accurate knowledge of the wave-lengths of the lines used in both the comparison and stellar spectrum. Accurate values of the absolute wave-lengths are not required, but their relative values must be well determined. For example, a relative error of $\pm$ 0.01 tenth-meter in the wave-length

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[1] *Publications* of the Yerkes Observatory, Vol. II, 1903.

of any line would produce an error in the velocity for that line of nearly a kilometer. The only system of wave-lengths which is at present available for our purpose is that due to ROWLAND, and this system has been generally adopted by line-of-sight observers. It has been shown,[1] however, that errors in relative wave-length exist in ROWLAND'S tables, amounting in some cases to as much as .01 or .02 tenth-meters. Furthermore the adjustment of the wave-lengths of the solar spectrum to those of the laboratory metallic spectra was not accomplished in a manner free from objections, so that systematic differences between the two result. Another difficulty arises, in the case of obtaining wave-lengths for stellar lines, due to the fact that stellar spectrographs have not sufficient resolution to separate lines which were measured as separate lines by means of the more powerful instrument used by ROWLAND. It is the practice of many observers, where two lines merge together to form one line in the star spectrum, to take the mean of the wave-lengths of the component lines weighted according to the intensities given by ROWLAND for those lines in the Sun. Wave-lengths based on estimates of intensities should naturally be regarded with suspicion, and in fact we do not know until the entire plate has been reduced whether we have chosen an erroneous wave-length or not. After we have reduced a number of plates of stars of the same type, we can correct the wave-lengths of those lines which consistently give residuals of the same sign. Comparison lines which consistently fall off the curve drawn for the other comparison lines are corrected in like manner.

It is known, too, that various stellar lines and blends behave differently for stars of different types.[2] It is assumed that lines in solar-type stars have the same wave-lengths as similar lines in the Sun. In the case of other types the solar lines which occur can be used in determining the wave-lengths of the non-solar lines and blends. In this way special tables are constructed for stars of different types.

The two methods of measurement and reduction which follow eliminate the sources of errors incident to the above methods as far as it is possible to do so. The first is that due

[1] See articles by FABRY and PEROT, *Astrophysical Journal*, Vol. 15, 270, 1902; EBERHART, Ibid., Vol. 17, 141, 1903; and HARTMANN, Ibid., Vol. 18, 167, 1903.

[2] S. ALBRECHT, *Astrophysical Journal*, Vol. 24, 333, 1906.

to Mr. R. H. Curtiss,[1] and is called by him "The Velocity Standard Method."

II. *The Velocity Standard Method.*—The method is in brief as follows: A standard velocity plate (*i. e.* a plate of a source whose velocity is accurately known), and the stellar plates are produced, as nearly as possible, under the same conditions of instrument, exposure, comparison spectra, etc. The measures of this standard plate fix the relative positions of the lines of the spectrum of the source and those of the comparison spectrum for a known velocity. These settings we call our zero velocity table. Now, measure the same lines, comparison and stellar, on the plate of the star whose velocity is to be determined. By a plot of the differences between the settings on the comparison lines of the standard and stellar plates the star plate is reduced to the dispersion of the standard plate. If the corrections from this plot are applied to the star lines, the differences between the measured positions of corresponding Fraunhofer lines in the standard and star spectra will be proportional to the difference of radial velocity of the sources producing them. It is usual to take a plate of the Sun or sky spectrum as the standard velocity plate, or several plates of either, all reduced to the same dispersion, from which to construct a zero-velocity table. It will be seen that the accurate wave-lengths of the lines of either comparison or stellar spectrum are not required in the above process of reductions, and in fact it is necessary to know them only roughly (to about 0.1 tenth-meter) for the computation of the factor rV_s. The assumption of the method is fundamental to all methods,—namely, that for solar-type stars the wave-lengths of the lines are the same as those of the corresponding lines in the Sun. For stars of other types it is necessary to form special tables for each type. The use of blends is based upon the assumption that the character of a blended line in the spectrum of a solar type star is the same as in the Sun, and is not dependent upon the estimated intensities of the component lines made by other observers. This freedom in the use of blends renders the method of great value not only to those using high-dispersion spectrographs but especially to those using low-dispersion instruments.

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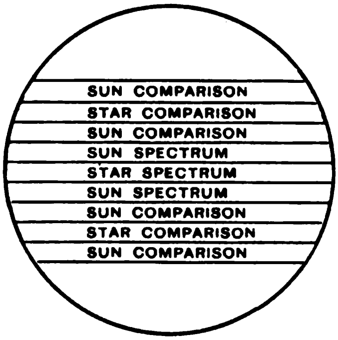
[1] Curtiss, *Astrophysical Journal*, Vol. 20, 149, 1904; *L. O. Bulletin* No. 62, 1904.

III. *The Spectrocomparator.*[1]—The last method to be discussed and the one most recent, is that due to Professor HARTMANN. It is in principle the same as the preceding method, except that the star plate is referred to the standard plate directly on the engine, in place of using a table of settings obtained from the standard plate. In order to accomplish this, he has designed a special form of measuring-engine known as the spectrocomparator. The instrument is provided with two plate carriages, one of which is movable. On one of the carriages the star plate is placed, and on the other, which is provided with a fine micrometer screw, is placed a standard plate of the Sun (obtained with the stellar spectrograph). The microscope has two objectives so arranged that the images of portions of the two plates are brought, by means of total reflecting prisms and a reflecting surface, to focus in the same plane and in the field of one eye-piece. Three strips of the surface of one of the prisms are silvered. These act as diaphragms in the path of rays coming from the Sun plate and as reflectors in the path of rays coming from the star plate. One of them cuts out the central strip of the Sun spectrum and throws into its place the central strip of the star spectrum. The other two cut out central strips of the comparison spectra of the Sun plate and throw into their places central strips from the comparison spectra of the star plate. The arrangement of the spectra in the field of view is as shown in the diagram.



By changing the relative magnifying powers of the two objectives he is able to produce the effect of making the dispersion of the two plates the same. The method of measurement is, then, after proper alignment of the plates, to bring corresponding sections of the two plates into the field of the microscope, set the corresponding lines of the two comparison spectra in the same straight line, and read the micrometer head. The Sun plate is then moved along

[1] Potsdam *Publications*, Vol. 18, 1906; also, *Astrophysical Journal*, Vol. 24, 285, 1906.

by the micrometer-screw until corresponding lines in the solar spectrum are in the same straight line with those of the star spectrum. The difference of the readings in the two positions is the displacement of the star lines relative to the solar lines, and is proportional to the difference in radial velocities of the star and Sun. The spectrum is divided into several sections for each of which these settings are made. The plates are then reversed and the measures repeated, care being taken that the second measure is made at a point of the screw 180° from that of the first. This method of procedure eliminates the physiological error dependent upon the positions of the plates and the periodic errors of the screw. The mean of the displacements in the two positions multiplied by the r (let us call it s) for each section gives for each the value $V_* - V_\odot$ where V_* is the radial velocity of the star and $V_\odot$ the radial velocity of the Sun. In taking the mean,[1] the values $V_* - V_\odot$ for the different sections are not of equal weight, since the displacements in the violet region of the spectrum, where the dispersion is greater, are measured with a higher percentage of accuracy than those in the region of longer wave-lengths. Assume that the probable error of the measure of the line displacement is the same for all sections. Then the values $V_* - V_\odot = sd$ should receive weights proportional to $\frac{1}{s}$ in taking the mean.

$$\text{The mean} = M_2 = \frac{\Sigma \frac{1}{s}(V_* - V_\odot)}{\Sigma \frac{1}{s}} = \frac{\Sigma d}{\Sigma \frac{1}{s}}.$$

He now puts $f = \frac{1}{2\Sigma\frac{1}{s}}$ and since $\Sigma d = \frac{1}{2}(\Sigma d_1 - \Sigma d_2)$ where d_1 and d_2 are the displacements in the direct and reverse measure, it follows that $M_2 = f(\Sigma d_1 - \Sigma d_2)$. This leads to a very simple method of computation. Take the sum of the displacements in the direct and reverse measures and multiply by a factor which is a constant so long as the same regions are used and whose values are computed for all combinations of regions that are used. The product $= M_2$. The correction for the velocity of the original Sun plate $V_\odot$ gives the radial velocity of the star relative to the observer. The reduction to the Sun is made in the usual way.

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[1] HARTMANN uses a camera lens giving good focus over a long [illegible] In stars of later types he is able to measure a length of spectrum [illegible] λ 4060. In this extent of spectrum the change of dispersion [illegible] the above correction appreciable. It is negligible [illegible] to a spectrum of only two or three hundred tenth-meters in length.

The great advantage claimed for the method, aside from those which it possesses in common with the velocity standard method, is that we are able to measure and reduce, in an hour or so, a plate of a star of a type rich in lines (several hundred on a plate) and practically utilize all the material on the plate. With the older methods to make such a measure and reduction utilizing all of the lines on the plate would require one or two days.

In Conclusion.—For the measure and reduction of spectrograms of stars of the earlier types, the use of the Cornu-Hartmann dispersion formula will suffice, in as much as the spectra of such stars consist of lines due to the simple gases, the wave-lengths of which have been accurately determined in the laboratory.

The measure and reduction of spectrograms of stars of the solar and later types will be accomplished with great saving of time and labor, and, moreover, by a method free from some of the uncertainties of wave-lengths by the use of the spectro-comparator. If the observer is not provided with such an instrument, the standard-velocity method would be used, in preference to any dispersion formula method, at least until a system of wave-lengths of the requisite accuracy is available.

For the case of later type stars it will be necessary to make corrections for the variation of lines with spectral type. It should be noted, however, that the corrections for some lines are positive while for others they are negative, so that the effects due to the variation of lines in stellar spectra of different types are to some extent compensating in radial velocity determinations.

MT. HAMILTON, CAL.

OPPORTUNITIES FOR SOLAR RESEARCH.[1]

BY GEORGE E. HALE.

It is safe to say that every astronomer would prize an opportunity to observe any of the fixed stars from a position where its disk would appear as large as the Sun. It does not seem probable, however, that such observations of stellar phenomena can ever be made, except in the case of the Sun itself. For it should ever be borne in mind, when considering the importance of solar research, that our most intimate knowledge of stellar phenomena must be derived from solar observations. In the case of the other stars, we may determine their positions, measure their radial velocities, observe their brightness, and analyze their light, but we have no means of studying the details of their structure, which must be understood before we can advance far in the solution of the great problem of stellar development. Thus we are driven back to the Sun, and forced to the conclusion that this typical star well deserves our most serious attention, and the application of every available means of research.

One cannot but be impressed, when considering the Sun from this standpoint, with the comparative neglect of the numerous opportunities awaiting the student of solar physics. It is possible, by the application of easily available instruments, for any careful student, wherever situated, to solve solar problems of great importance. If space permitted, it could be shown that almost all of the apparatus required in such work can be constructed at very small expense. For our present purpose, however, let us assume that the observer has at his disposal one of the cœlostats so commonly employed in eclipse work. If this cœlostat has a rather thick mirror, which is frequently resilvered, it may be depended upon to serve well for solar work, provided that the mirror is shielded from sunlight during the intervals between the exposure of photographs, and that these exposures are made as short as possible. We may assume that the sunlight is reflected from the cœlostat mirror to a second plane mirror (which should

[1] Read before the Astronomical and Astrophysical Society of America, New York, December, 1906.

also be as thick as possible) and from this mirror to an objective, which should have an aperture of at least six inches and a focal length of from forty to sixty feet. In place of this objective, a concave mirror, of similar aperture and focal length, may be employed. This apparatus will furnish the necessary means of forming a fixed solar image, of large diameter, within a laboratory, where accessory apparatus can be mounted. Let us now consider briefly some of the investigations that can be undertaken.

DIRECT PHOTOGRAPHY.

The routine photographic work, done under the direction of the Greenwich Observatory, provides ample material for the study of the positions and motions of sun-spots, but special investigations may well be undertaken with the aid of direct photographs. The important thing in all solar work is not merely to make observations of some single phenomenon, but to carry on two or three series of carefully correlated observations, so designed as to throw light on one another. For example, Mr. MAUNDER has recently found that the rotation periods of sun-spots in nearly the same latitude show differences as great as those encountered in passing from the equator to the highest latitude in which the spots are found. The cause of such differences may well be a subject of most careful investigation. The proper motions of spots, which are associated with their period of development, must be fully taken into account. We might also make the hypothesis, merely for the purpose of testing the question, that the rotation period of a sun-spot depends upon its level with respect to the photosphere. For this reason it would be desirable to investigate, in connection with the study of rotation, the question of the level of sun-spots. A simple means of doing this will be mentioned later. But it may be added here that the question of level raises other considerations, which should not be left out of account. It is probably worth while to investigate photographically the old Wilsonian hypothesis, since visual observations have proved so discordant in attempts to determine the relative widths of the preceding and following penumbra of spots at various distances from the center of the Sun. As a sun-spot is depressed below the level of the surrounding faculæ, the vexed question of the visibility of

the umbra near the limb may depend upon whether the faculæ are present or missing on the sides lying in the line of sight. It is quite possible that the temperature of the umbra may vary with its distance above the photosphere. Thus correlation between observations bearing on spot level and observations of spot spectra is desirable.

SPECTROSCOPY.

The spectroscopic study of solar phenomena has been greatly retarded through delay in adopting suitable instruments. The short-focus spectroscopes attached to equatorial telescopes are admirably adapted for visual observations, but in photography their linear dispersion is much too small to realize the full resolving power of the grating employed. In laboratory work, on the contrary, while the spectroscopes have been sufficiently powerful, they have usually been of the concave grating type, where astigmatism interferes seriously with the study of solar details, and the solar image on the slit of the spectroscope has been so small that the individual phenomena, in any event, could not be separately distinguished.

The preparation of a powerful spectrograph of the Littrow type is an extremely simple matter. A small slit, mounted on a short metallic tube, is supported immediately above a long narrow photographic plate. The wooden support for plate-holder and slit rests on a pier and forms the end of a long light tube of rectangular section, which is closed at its other end by the wooden support of the lens which serves at once for collimator and camera. The angular aperture of this lens is of course defined by that of the objective which forms the solar image on the slit, but if possible its focal length should be from ten to twenty feet. The rays, after being rendered parallel by the lens, fall upon a grating, which need not be larger than a four-inch (a much smaller one would do very useful work). The spectra should be photographed in the second, third, or fourth order, so as to give sufficient scale.

With such an instrument, new work of great value may be done. Even with a very small solar image, a photographic study of the solar rotation should yield results of great precision. HALM believes, from his spectroscopic work, that the rotation period varies with the solar activity. This is yet to be confirmed, but the question well deserves investigation.

There is some reason to think that the rotation period is not the same for different substances in the reversing layer. The iron lines, for example, may give values different from those obtained with the carbon lines. It is also interesting to inquire whether the "enhanced" lines of an element give the same period as the other lines in its spectrum.

Another interesting investigation, which does not require a large solar image, is the study of the radial velocity of the calcium vapor in the flocculi. It is only necessary to measure, with great precision, the wave-lengths of the H_2 and H_3 lines, corresponding to various points on the solar image. In this way the rise or fall of the calcium vapor in the flocculi can be ascertained. To be of the most service, this investigation should be carried on in conjunction with some other study of the flocculi.

The photographic study of sun-spot spectra offers a most promising opportunity. It is a very easy matter to photograph spot spectra in such a way as to record for study thousands of lines which are beyond the reach of visual observations. Nevertheless, this has been accomplished only recently, simply because spectrographs of suitable design have not previously been applied in this work. At the Solar Observatory on Mt. Wilson it has been found that in general the lines strengthened in spot spectra are strengthened in the laboratory when the temperature of the vapor is reduced, while the lines that are weakened in sun-spots are weakened in the laboratory under the same conditions. Thus it appears probable that the temperature of the spot vapors is below that of the reversing layer. This conclusion has been confirmed by the discovery in the spot spectrum of the flutings of titanium oxide. This molecule thus exists at the lower temperature of the sun-spot, but is broken up at the higher temperature of the reversing layer. The bearing of this result upon stellar spectroscopy will be seen when it is remembered that the flutings of titanium oxide form the principal feature of the spectrum of the third-type stars. It has also been found that *Arcturus* gives a spectrum resembling very closely the spectrum of a sun-spot. A further study of this question will require a large number of observations of spot spectra, with special reference to possible variations in temperature, as indicated by variations in the relative intensity of the spot lines. As already remarked,

the temperature of spots may also depend upon their level, and this possibility must be borne in mind.

WORK WITH THE SPECTROHELIOGRAPH.

It is perhaps commonly supposed that the spectroheliograph is necessarily an expensive instrument, out of reach of the average observer. As a matter of fact, however, a spectroheliograph capable of giving the best results can easily be constructed of materials ordinarily available in any observatory or physical laboratory. It is sufficient, for many purposes, to photograph only a narrow zone of the solar image. In this case small lenses will suffice for the collimator and camera, and small prisms for the optical train. The lenses and prisms may be mounted in wooden supports, on a wooden platform, rolling on four steel balls in V-shaped tracks. The motion of the instrument across the solar image may easily be produced by a simple screw, driven by a small electric motor. Such a spectroheliograph was used to good purpose at the Solar Observatory before the permanent instrument was completed.

Brief mention may be made of some of the numerous investigations possible with such an instrument. It has recently been found at the Solar Observatory that the dark hydrogen flocculi, photographed near the Sun's limb, are slightly displaced with reference to the corresponding calcium flocculi. In general, they lie nearer the limb. This probably indicates that the absorbing hydrogen clouds are on the average at a higher level than the brilliant calcium clouds. This subject deserves careful investigation, extending over a considerable portion of time. The type of spectroheliograph just referred to is as suitable for the purpose as any instrument that can be constructed. Another question, which seems to be somewhat more difficult to solve, is the actual difference in elevation of the calcium flocculi, as photographed in the H_1 and H_2 lines. Indeed, it is still a question as to how important a part the dense calcium vapor plays in determining the form of the H_1 flocculi. These objects resemble the faculæ so closely that they appear practically identical with them, though slight differences, which are apparently genuine, are occasionally found.

Another method of investigating this whole question of levels is afforded by the spectroheliograph. It will be remem-

bered that when the level of sun-spots was last under discussion reference was made to the relative radiation of the umbra and neighboring photosphere, corresponding to different distances from the center of the Sun. It was pointed out that when the spot approaches the limb its radiation decreases less rapidly than that of the photosphere. The natural conclusion was that the spot lies at a higher level than the photosphere, and thereby escapes much of the absorption produced by a comparatively thin layer of absorbing matter. Recent observations at Mt. Wilson have shown, however, that the proportion of violet light in sun-spots is much smaller than in the case of the photosphere. As it is known that the violet rays undergo much more absorption near the Sun's limb than those of greater wave-length, it is obvious that the light of the spot would suffer less absorption, even if it were at the same level as the photosphere. Thus the only proper method of investigating this question will be through the use of monochromatic light.

The spectroheliograph affords a simple means of accomplishing this. It is only necessary to make photographs of the spot and adjoining photosphere, corresponding to various distances from the Sun's center. The camera slit should be set on the continuous spectrum (not on a line), preferably in the violet or ultra-violet, since the change of absorption would be most felt in this region. In order to make photographic comparisons easily possible, the intensity of the photosphere should be reduced to approximately the intensity of the umbra, by means of a dark glass, mounted over the collimator slit, but not covering that part of the slit through which the light of the umbra passes. It is obvious that a large image of the Sun will be required in this work.

The spectroheliograph can be applied to other studies of absorption. The H_1 flocculi, for example, are reduced in brightness near the Sun's limb much more than the H_2 flocculi, presumably because the latter lie at a higher level. These differences can be studied photometrically on spectroheliograph plates made for the purpose. In the same way the H_1 flocculi can be compared with the faculæ. Since it is a question just what level is represented by the background (between the flocculi) in calcium, hydrogen, or iron photographs, the instrument should be arranged so as to permit photometric com-

parisons of this background with the photosphere, photographed with light from the continuous spectrum immediately adjoining the calcium, hydrogen, or iron line employed for the flocculi.

These new applications of the spectroheliograph have only recently occurred to me, and are mentioned because of their suitability for use with instruments containing prisms of ordinary height, capable of photographing only narrow zones of the solar image. Numerous other problems might be mentioned, such as the comparative study of H_1, H_2, and H_3 photographs, and of calcium, hydrogen, and iron images; the distribution of the flocculi in latitude and longitude; their varying area, as bearing on the solar activity and on terrestrial phenomena; and their motion in longitude, as measuring solar rotation. But limitations of time forbid more than a mere reference to work and methods the details of which are discussed elsewhere. My purpose has been accomplished if I have shown that with comparatively simple instrumental means any careful observer may secure important results. In much of this work it is desirable that investigators occupied with similar problems should co-operate with one another. The International Union for Co-operation in Solar Research was organized with this end in view. It has already inaugurated solar studies on a common plan in several different fields, and is preparing to extend the range of its activities in the near future.

NOTE ON THE DISTRIBUTION OF DOUBLE STARS IN THE ZONE $+56°$ TO $+90°$.[1]

By R. G. Aitken.

The main object of the survey of the sky that has been in progress at the Lick Observatory for the past seven years is to accumulate data for a statistical study of the number and the distribution in space of the double stars whose combined magnitude is brighter than 9.1 of the B. D. scale, and whose angular separation is less than 5″. This survey is now well advanced toward completion, so far as the sky area

[1] Read before the Astronomical and Astrophysical Society of America, New York, December, 1906.

north of — 22° Declination is concerned, and it becomes a matter of interest to ascertain what kinds of data it is likely to yield.

In general, the various 4° zones into which the sky was divided for this survey have not yet been completely examined, the winter hours of Right Ascension, from 7^h to 14^h, being considerably less advanced than the remaining portion. But the entire area north of + 56° has been examined, and I have tabulated the results. Some of these tabulations and my conclusions based upon them I desire to present briefly.

The region named was divided into eight zones, of which Professor HUSSEY examined four,—namely, + 60° to + 64°, + 64° to + 68°, + 76° to + 80°, + 80° to + 84°, and the writer the remaining four. Professor HUSSEY included the 9.1 B. D. stars in his search, while I examined only those as bright as 9.0. In the following discussion only the stars to 9.0 are included.

As the area north of + 60° was almost entirely examined with the 12-inch telescope, while about one half of the zone, + 56° to + 60°, was examined with the 36-inch, the latter is considered separately.

It has been the experience of both observers that, under good conditions, a double star with nearly equal components will be recognized with certainty with the 12-inch telescope if the distance is as great as 0″.25; in fact, we have each discovered several pairs with that instrument whose distances, measured later with the 36-inch, were found to be well *under* 0″.25. If the two components differ two or more magnitudes, we cannot be sure to detect the duplicity if the distance is much under 1″. If the distance is 2″ or more, a companion as faint as 13 or 13½ magnitude will be seen readily.

Since every previously known double star as bright as 9.0 magnitude was carefully identified in the course of the search, the fact that they were first seen with telescopes of very different apertures has no bearing upon the present discussion, so that the results given for the zone + 60° to + 90° may be considered to be based entirely upon the separating power of the 12-inch telescope.

By actual count of the stars on the charts used in the search, I find that in the region north of + 60° we have examined 12,299 stars of 9.0 magnitude or brighter. Of these, 294 were

known double stars, and 259 more were found to be double during our survey, giving a total of 553 pairs in this sky area. This includes seven bright stars with distances exceeding 5″, and excludes duplicates. That is, when we have found that one component of a Struve or other known pair is itself double only the closer pair is counted.

It appears, then, that one star in 22¼ in this region is a close double within the separating power of a good 12-inch telescope, a ratio somewhat smaller, as I have reason to believe, than will be found to hold for the sky in general. The tables that accompany this note exhibit the distribution of these pairs. Table I gives the number of new discoveries and the number of previously known double stars in each zone and for each six hours of Right Ascension. Table II combines the new and old pairs for each hour of Right Ascension for the whole region and for the two zones + 60° to + 68° and + 68° to + 90° separately.

TABLE I. + 60° TO + 90°.

QUADRANT I. 0^h TO 6^h.

Zone.	Double Stars. New.	Double Stars. Old.	Double Stars. Total.	Stars to 9.0 Mag.	Ratios. New D. S. to 9.0 Stars.	Ratios. D. Stars to 9.0 Stars.
84° to 90°	0	4	4	107	1 :	1 : 26.8
80 to 84	2	5	7	193	1 : 96.5	1 : 26.2
76 to 80	7	10	17	330	1 : 47.2	1 : 19.4
72 to 76	14	10	24	418	1 : 29.9	1 : 17.4
68 to 72	11	12	23	574	1 : 52.2	1 : 23.0
64 to 68	21	21	42	691	1 : 33.0	1 : 16.5
60 to 64	25	31	56	1041	1 : 41.6	1 : 18.6

QUADRANT II. 6^h TO 12^h.

Zone.	New.	Old.	Total.	Stars to 9.0 Mag.	New D. S. to 9.0 Stars.	D. Stars to 9.0 Stars.
84° to 90°	3	0	3	110	1 : 36.7	1 : 36.7
80 to 84	4	3	7	193	1 : 48.2	1 : 27.6
76 to 80	2	2	4	281	....	1 : 70.2
72 to 76	6	7	13	337	1 : 56.2	1 : 25.9
68 to 72	5	7	12	405	1 : 81.0	1 : 33.8
64 to 68	10	12	22	519	1 : 51.9	1 : 23.6
60 to 64	12	14	26	639	1 : 53.2	1 : 24.6

QUADRANT III. 12^h TO 18^h.

Zone.	New.	Old.	Total.	Stars to 9.0 Mag.	New D. S. to 9.0 Stars.	D. Stars to 9.0 Stars.
84° to 90°	1	3	4	130	1 :	1 : 32.2
80 to 84	2	5	7	191	1 : 95.5	1 : 27.3
76 to 80	5	3	8	288	1 : 57.6	1 : 36.0
72 to 76	5	4	9	372	1 : 74.4	1 : 41.1
68 to 72	10	7	17	461	1 : 46.1	1 : 27.1
64 to 68	12	6	18	545	1 : 45.4	1 : 30.3
60 to 64	12	11	23	610	1 : 50.8	1 : 26.5

QUADRANT IV. 18^h TO 24^h.

Zone.	Double Stars. New.	Old.	Total.	Stars to 9.0 Mag.	Ratios. New D. S. to 9.0 Stars.	Ratios. D. Stars to 9.0 Stars.
84° to 90°	2	2	4	117	1 : 58.5	1 : 29.2
80 to 84	3	7	10	219	1 : 73.0	1 : 21.9
76 to 80	9	6	15	328	1 : 36.4	1 : 21.9
72 to 76	15	12	27	412	1 : 27.5	1 : 15.3
68 to 72	14	16	30	587	1 : 41.9	1 : 19.6
64 to 68	21	21	42	965	1 : 46.0	1 : 23.0
60 to 64	26	53	79	1236	1 : 47.5	1 : 15.6

SUMMARY.

Quadrant I	80	93	173	3354	1 : 41.9	1 : 19.4
II	42	45	87	2484	1 : 59.1	1 : 28.6
III	47	39	86	2597	1 : 55.3	1 : 30.2
IV	90	117	207	3864	1 : 42.9	1 : 18.7
Total	259	294	553	12299	1 : 47.5	1 : 22.24

TABLE II.

RATIOS OF DOUBLE STARS TO STARS 9.0 OR BRIGHTER, BY HOURS OF R. A.

R. A.	Zone + 60° to + 90°.	Zone + 68° to + 90°.	Zone + 60° to + 68°.
0^h	28 : 624 = 1 : 22.3	12 : 262 = 1 : 21.6	16 : 362 = 1 : 22.6
1	33 : 644 = 1 : 19.5	18 : 278 = 1 : 15.4	15 : 366 = 1 : 24.4
2	29 : 611 = 1 : 21.1	13 : 293 = 1 : 22.5	16 : 318 = 1 : 19.9
3	27 : 547 = 1 : 20.3	8 : 275 = 1 : 34.4	19 : 272 = 1 : 14.3
4	31 : 497 = 1 : 16.0	13 : 277 = 1 : 21.3	18 : 220 = 1 : 12.2
5	25 : 431 = 1 : 17.2	11 : 237 = 1 : 21.5	14 : 194 = 1 : 13.9
6	11 : 439 = 1 : 39.9	6 : 226 = 1 : 37.7	5 : 213 = 1 : 42.6
7	14 : 432 = 1 : 30.9	6 : 239 = 1 : 39.8	8 : 193 = 1 : 24.1
8	16 : 411 = 1 : 25.7	5 : 211 = 1 : 42.2	11 : 200 = 1 : 18.2
9	19 : 416 = 1 : 21.9	13 : 221 = 1 : 17.0	6 : 195 = 1 : 32.5
10	10 : 394 = 1 : 39.4	3 : 211 = 1 : 70.3	7 : 183 = 1 : 26.1
11	17 : 392 = 1 : 23.1	6 : 218 = 1 : 36.3	11 : 174 = 1 : 15.8
12	9 : 375 = 1 : 41.7	7 : 220 = 1 : 31.4	2 : 155 = 1 : 77.8
13	11 : 414 = 1 : 37.6	6 : 226 = 1 : 37.7	5 : 188 = 1 : 37.6
14	10 : 375 = 1 : 37.5	6 : 190 = 1 : 31.7	4 : 185 = 1 : 46.2
15	21 : 462 = 1 : 22.0	7 : 260 = 1 : 37.1	14 : 202 = 1 : 14.4
16	16 : 480 = 1 : 30.0	9 : 268 = 1 : 29.8	7 : 212 = 1 : 30.3
17	19 : 491 = 1 : 25.8	10 : 268 = 1 : 26.8	9 : 223 = 1 : 24.8
18	25 : 524 = 1 : 21.0	13 : 272 = 1 : 20.9	12 : 252 = 1 : 21.0
19	24 : 650 = 1 : 27.1	10 : 259 = 1 : 25.9	14 : 391 = 1 : 29.4
20	25 : 557 = 1 : 22.3	11 : 257 = 1 : 23.4	14 : 300 = 1 : 21.4
21	43 : 696 = 1 : 16.2	13 : 248 = 1 : 19.1	30 : 448 = 1 : 14.9
22	44 : 686 = 1 : 15.6	18 : 319 = 1 : 17.7	26 : 367 = 1 : 14.1
23	46 : 751 = 1 : 16.3	21 : 308 = 1 : 14.7	25 : 443 = 1 : 17.7

SUMMARY.

Quadrant.			
I	173 : 3354 = 1 : 19.4	75 : 1622 = 1 : 21.6	98 : 1732 = 1 : 17.7
II	87 : 2484 = 1 : 28.6	39 : 1326 = 1 : 34.0	48 : 1158 = 1 : 24.1
III	86 : 2597 = 1 : 30.2	45 : 1432 = 1 : 31.8	41 : 1165 = 1 : 28.4
IV	207 : 3864 = 1 : 18.7	86 : 1663 = 1 : 19.3	121 : 2201 = 1 : 18.2
Total	553 : 12299 = 1 : 22.24	245 : 6043 = 1 : 24.7	308 : 6256 = 1 : 20.3

It is at once apparent from these tables that the double-star distribution follows in a general way the distribution of all stars to 9.0 magnitude, and if the numbers in Table II are plotted the resemblance of the curves is striking.

But an unexpected feature of the distribution is the fact that the double stars are *relatively as well as absolutely more numerous in the richer sky areas,* the numbers in the four quadrants of Right Ascension being very nearly as 2 to 1 to 1 to 2.4 while the numbers of the stars to 9.0 magnitude are about as 1.3 to 1 to 1 to 1.5. When the zones $+60°$ to $+68°$ and $+68°$ to $+90°$ are taken separately the same relation is found in each.

My next effort was to determine whether a different relation would be shown by the closer pairs or by the brighter pairs. The pairs under 2″ were separately tabulated, then those under 1″, then the very close pairs, ⅓″ or less, and finally the pairs as bright as 7.5 magnitude. It is not necessary to give the details, but the results by quadrants are as follows:—

	I.		II.		III.		IV.	
	No.	Ratio.	No.	Ratio.	No.	Ratio.	No.	Ratio.
Under ⅓″......	15	1 : 224	9	1 : 276	11	1 : 236	24	1 : 161
" 1	76	1 : 44	37	1 : 67	40	1 : 65	80	1 : 48
" 2	113	1 : 30	56	1 : 44	66	1 : 39	132	1 : 29
" 5	173	1 : 19	87	1 : 29	86	1 : 30	207	1 : 19
7.5 Mag. or brighter	49	1 : 68	23	1 : 108	18	1 : 144	63	1 : 61

It is clear from an inspection of this table that the closer pairs, which may safely be classed as binary systems, follow the same general law of distribution as do all the pairs here considered, and also that magnitude does not materially affect the question. In fact, I find that the average magnitude of the closer pairs in the second and third quadrants is slightly greater, numerically, than that of the corresponding pairs in the other two. So far as this factor goes, therefore, rather more difficult pairs were detected in the second and third quadrants than in the first and fourth. The result is not

affected by the time of year in which the work was done, as only nights of good seeing were used, and, besides, the search in each quadrant extended over from six to nine months.

It may therefore be accepted as a fact that in the sky area from $+60°$ to the North Pole, *double stars of all classes up to 5″ separation are relatively more numerous in the region richest in stars to 9.0 magnitude*,—that is, in the region of the Milky Way.

The zone $+56°$ to $+60°$ contains 4,257 stars as bright as 9.0 that were actually examined with the telescope. The fourth quadrant was almost wholly surveyed with the 12-inch, the first with the 36-inch, and the other two about in equal parts with the two telescopes. Of these stars 114 were known double stars and 130 more were found to be double, making a total of 244 pairs, or a ratio of 1 to 17.4. When the numbers of double stars and of stars to 9.0 in each hour of Right Ascension are plotted the two curves again show a very marked similarity.

Grouped by quadrants, we find the following relations:—

	Stars to 9.0.	Double stars.	Ratio.
I	1413	98	1 : 14.4
II	716	35	1 : 20.4
III	672	30	1 : 22.4
IV	1456	81	1 : 18.0

Thus in this zone, too, we find that the double stars are relatively more numerous in the regions richest in stars to 9.0 magnitude, though the curve is somewhat affected, as one would expect, by the fact that the fourth quadrant was examined with a much less powerful instrument than the other three, especially the first.

When the ratios are taken by zones of Declination, we find:—

Zone.	Ratio.	Zone.	Ratio.
$+84°$ to $+90°$	1 : 30.9	$+68°$ to $+72°$	1 : 24.7
$+80$ to $+84$	1 : 25.7	$+64$ to $+68$	1 : 21.9
$+76$ to $+80$	1 : 27.9	$+60$ to $+64$	1 : 19.2
$+72$ to $+76$	1 : 21.1	$+56$ to $+60$	1 : 17.4

The charts used in the survey give evidence of local irregularities in the distribution of the double stars, the ratio in some areas of 15 to 20 square degrees being as high as 1 to 7 or 8 and in others as low as 1 to 50. The study of these irregularities is deferred to the time when the whole northern

hemisphere shall have been examined, when a division of the sky into small sections of approximately equal area will make it possible to decide whether there is any marked tendency toward gregariousness on the part of the double stars and also whether, as a whole, they are distributed symmetrically relatively to some plane,—as, for instance, that of the Milky Way.

LICK OBSERVATORY, December 4, 1906.

ASTRONOMICAL OBSERVATIONS IN 1906.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

Z *Cygni*.[1]

Jan. 20:	Z = c.	Aug. 31:	$\left\{\begin{array}{l} < b'. \\ > b. \end{array}\right.$
Apr. 8:	invisible.	Sept. 8:	= b.
14:	< e.	19:	id.
22:	id.	24:	id.
May 24:	id.	Nov. 10:	1 step > e.
July 26:	= b.	13:	1 step < e.
Aug. 19:	$\left\{\begin{array}{l} < a. \\ > b'. \end{array}\right.$	Dec. 4:	3 steps < e.
24:	= b'.	9:	id.
27:	id.	23:	invisible.

S *Ursæ Majoris*.[2]

Jan. 1:	S = g.	May 23:	= e.
19:	f'.	July 26:	invisible.
Feb. 28:	1 step < e.	Aug. 19:	= g.
Mar. 14:	= d.	24:	$\left\{\begin{array}{l} > g. \\ < f. \end{array}\right.$
19:	id.	Aug. 27:	id.
29:	2 steps > d.	31:	id.
Apr. 2:	id.	Sept. 5:	1 step > f'.
5:	$\left\{\begin{array}{l} 4 \text{ steps} > d. \\ 9 \text{ steps} < c. \end{array}\right.$	8:	$\left\{\begin{array}{l} < e. \\ > f'. \end{array}\right.$
8:	6 steps > d.	10:	id.
10:	id.	12:	id.
12:	id.	19:	id.
14:	4 steps < c.	21:	1 step < e.
22:	id.	23:	id.
May 11:	= d.		

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[1] Vide the sketch in the *Publications A. S. P.*, No. 100, p. 16.

[2] Vide the sketch in the *Publications A. S. P.*, No. 73, p. 56.

Sept. 24: id.
27: = e.
Oct. 11: = d.
Nov. 10: 4 steps > d.
13: id.
Dec. 4: 1 step > d.
9: 3 steps > d.
23: = e.

T *Ursæ Majoris.*[1]

Jan. 1: T = d.
19: 1 step > e.
Feb. 28: invisible.
Mar. 14: id.
19: id.
29: id.
Apr. 5: id.
10: id.
12: id.
14: id.
22: id.
May 5: id.
July 26: { < a. / > b.
Aug. 19: = b.
24: id.
27: { < a. / > b.
Aug. 31: id.
Sept. 5: = b.
8: id.
10: id.
12: id.
19: { < b. / > c.
21: 1 step > c.
23: id.
24: id.
27: = c.
Oct. 11: 1 step < d.
Nov. 10: = f.
13: < g.
Dec. 4: invisible.
9: id.
23: id.

W *Pegasi.*[2]

Jan. 1: W 1 step > e.
2: id.
19: 1 step > c.
July 26: invisible.
Aug. 19: < n*.
24: id.
Sept. 19: < h.
Oct. 11: 1 step < g.
Nov. 10: = g.
13: = f.
Dec. 4: 1 step > e.
9: 1 step < d.
10: = d.
23: 2 steps > c.

* n is a star between W and b.

SS *Cygni.*[3]

P.M.
Jan. 2, 6^h: SS < g.
20, 6^h: 1 step < g.
Apr. 7, 14^h: < d.
14, 9^h: < f.
22, 9^h: < d.
July 26, 11^h: = e.
28, 10^h: { < e. / > f.
Aug. 19, 10^h: = g*.

P.M.
Aug. 24, 10^h: = e.
27, 10^h: = c.
31, 10^h: { > c. / < b.
Sept. 5, 10^h: = c.
Sept. 8, 10^h: = d.
11, 10^h: 1 step > e.
12, 9^h: id.
19, 9^h: < g.

* g is the faint companion-star next c towards East.

[1] Vide the sketch in the *Publications A. S. P.*, No. 22, p. 63.
[2] Vide the sketch in the *Publications A. S. P.*, No. 60, p. 23.
[3] Vide the sketch in the *Publications A. S. P.*, No. 100, p. 18.

Sept. 21, 9^h:	id.	Dec. 4, 6^h:	1 step $<$ c.
24, 9^h:	$=$ h.	6, 6^h:	$=$ d.
Oct. 11, 9^h:	$=$ g.	9, 11^h:	$=$ e.
Nov. 10, 6^h:	id.	11, 6^h:	id.
13, 6^h:	id.	23, 6^h:	$=$ g.

Y *Tauri* (B. D. $+ 20°.1083$).

As comparison-stars I have used A $=$ B. D. $20°.1095$ ($7^m.4$) and b $=$ B. D. $+ 20°.1073$ ($8^m.2$). A third star, B $=$ B. D. $+ 20°.1093$ ($7^m.3$), I always find *smaller* than A.

Jan. 2:	$>$ b.	Apr. 5:	id.
19:	id.	12:	3 steps $>$ A.
Mar. 2:	$>$ A.	Sept. 27:	$>$ A.
14:	id.	Nov. 13:	$=$ A.
19:	$=$ A.	Dec. 4:	a little $>$ b.
20:	$>$ A.	9:	$\begin{cases} < \text{A.} \\ > \text{b.} \end{cases}$
29:	1 step $>$ A.		
Apr. 2:	id.	23:	id.

This irregular variable star seems to have had its greatest brightness about the spring and summer of 1906, while in the year 1905 its brightness had not reached that of the star A.

TV *Cygni.*

This star oscillates in brightness a little about $9^m.5$.. I have compared it with the stars b and c in the sketch by A. STANLEY WILLIAMS (*A. N.* 3629) and always found T V $<$ b.

Apr. 7, 14^h:	TV $=$ c.	Nov. 10, 6^h:	$\begin{cases} > \text{c.} \\ < \text{b.} \end{cases}$
July 26, 11^h:	$\begin{cases} > \text{c.} \\ < \text{b.} \end{cases}$	13, 6^h:	id.
Aug. 27, 10^h:	id.	Dec. 4, 6^h:	$=$ c.
Sept. 25, 12^h:	id.	23, 6^h:	$\begin{cases} > \text{c.} \\ < \text{b.} \end{cases}$
Oct. 11, 9^h:	id.		

FIREBALLS.

In the past year thirty-one fireballs have been seen from stations in Denmark. The details of the five most interesting of these meteors are here given, as follows:—

No. 1. April 11, 9^h 28^m P.M. An exploding meteor lightens up the whole region and disappears 30^{km} above the mouth of Horsens Fjord. The path of the meteor went steeply downwards.—22 reports.

No. 2. June 24, 11^h 3^m. Gigantic fireball over northern Jutland, where a detonation like rumbling of thunder was heard. The meteor probably exploded above the island Laesö, in Kattegat, and the phenomenon was seen at several places

in Denmark, Norway, and Sweden. Some newspapers reported that fragments of this meteor had fallen down in the duckyard of the Göteborg, "Gibraltar," but unfortunately it was only a "newspaper duck"!—23 reports.

No. 3. July 26, $11^h\ 28^m$. An exploding fireball with a great flashing light was seen from Odder in the east, leaving a 5°-long train; duration 30^s.—7 reports.

No. 4. November 23, $2^h\ 45^m$. A large fireball was seen from several places in Jutland, in spite of the dazzling sunshine, as a sparkling exploding meteor, leaving an extensive train for a moment; 30^{km} west from Horsens the meteor passed the zenith and over this region a loud detonation like thunder-roaring was heard. Some thought of a powder explosion; people ran out of the houses, thinking an earthquake had taken place; horses ran frightened about in the fields. The fireball exploded 60^{km} above the ground, and, according to its direction, this meteor may be noted as a "salutation from the Bielids," which were expected at that time.—12 reports.

No. 5. December 18, $6^h\ 10^m$. A flashing and exploding fireball was seen from Jutland in the southeast, not far from *Saturn*, as observed at Odder. Its train was straight for a minute, but in the next minute it was turning and winding. —10 reports.

Shooting-Stars.

In the period August 9th-12th corresponding observations were arranged for from seven stations in Denmark. The weather was not favorable, and our efforts succeeded only on August 12th. At these stations 122 paths of shooting-stars were mapped, but only six proved suitable for calculation. These six meteors have given the following results:—

For Observation.

No.	Time.	Station.	Beginning.	Ending.	Mag.	Observer.
1	Aug. 12, $10^h\ 14^m\ 0^s$ P.M.	Odder	....	316°.4 + 9°	2	T. Köhl.
		Nyborg	....	310 + 15	2	Ch. Frost.
2	Aug. 12, 10 21 45 P.M.	Odder	359° + 22°.8	353 + 13	4	T. Köhl.
		Nyborg	20 + 44	6 + 30 .3	2	Ch. Frost.
3	Aug. 12, 10 27 33 P.M.	Odder	....	292 + 30	2	T. Köhl.
		Nyborg	....	255 .5 + 57	2	Ch. Frost.
4	Aug. 12, 10 36 30 P.M.	Odder	40 + 40 .8	40 + 33	1	T. Köhl.
		Nyborg	56 .5 + 47	59 + 41 .2	2	Ch. Frost.
5	Aug. 12, 10 56 30 P.M.	Askov	50 .8 + 37 .2	54 .2 + 31 .7	♀	L. Dolleris
		Odder	47 + 40 .5	50 + 35	♀	T. Köhl.
		Nyborg	61 .8 + 46	71 + 42 .6	♃	Ch. Frost.
6	Aug. 12, 11 4 40 P.M.	Odder	....	351 + 23	1	T. Köhl.
		Nyborg	....	15 + 61 .3	1	Ch. Frost.

For Calculation.

No.	Beginning. h	λ	φ	Ending. h	λ	φ	Real Length of the Path. β	Radiant. AR	Decl.
1	....	......	....	51.9	1° 26.′6 w	54° 56′.4	....	....	......
2	95.1	0° 1′.4 e	55° 50′.1	102.4	0 32.0 e	55 26.4	55.6	153°	+22°.1
3	....	......	....	119.0	2 26.4 w	55 27.1	....	....	......
4	152.5	1 36.6 e	57 29.2	92.6	1 5.4 e	57 5.1	82.4	40.2	+66.6
5 AO	166.0	2 6.0 e	57 43.9	82.2	0 39.0 e	57 8.7	139.0	40.3	+49.9
5 AN	164.5	2 4.3 e	57 43.6	82.3	0 41.5 e	57 10.2	133.0	39.5	+50.3
5 ON	163.0	2 2.0 e	57 42.5	82.2	0 39.7 e	57 9.1	132.8	39.8	+50.3
6	....	......	....	83.1	1 3.2 w	55 39.3	....	....	......

h and *β* are expressed in kilometers; *λ* is longitude from Copenhagen; *φ* is north latitude; *h* is the altitude of the meteor above the Earth's surface.

Errata.

In the *Publications A. S. P.*, No. 89, p. 66, for *T U* read *R T* in the sketch as also in the text.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1907.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter..	Mar. 7, 12h 42m A.M.	Last Quarter..	Apr. 5, 7h 20m A.M.
New Moon...	" 13, 10 5 P.M.	New Moon...	" 12, 11 6 A.M.
First Quarter.	" 21, 5 10 P.M.	First Quarter.	" 20, 12 38 P.M.
Full Moon...	" 29, 11 44 A.M.	Full Moon....	" 27, 10 5 P.M.

The Sun passes the vernal equinox and spring begins about 10 A.M., Pacific time, March 21st.

Mercury is an evening star at the beginning of March, setting about an hour and one half after sunset, and will be

an easy object for a few days about that date on clear evenings. It comes to greatest east elongation on March 1st, 18° 10′. This is a much smaller greatest elongation than the average, as it comes less than three days after perihelion. The planet approaches the Sun quite rapidly after the first few days of the month, passing inferior conjunction on the night of March 17-18th and becoming a morning star. It then moves rapidly away from the Sun, reaching greatest west elongation on April 14th. Its apparent distance from the Sun will then be 27° 36′, which is fifty per cent greater than its distance at the time of greatest east elongation in March; but the conditions for visibility are not nearly as good, as *Mercury* is now 13° south of the Sun, and rises less than an hour before sunrise, so that it will be impossible to see it with the naked eye.

Venus is still a morning star, rising 2^h 20^m before sunrise on March 1st, 1^h 38^m on April 1st, and 1^h 20^m on April 30th. The planet passed greatest west elongation on February 8th, and is now nearing the Sun, but the main cause of the diminution of the interval between the rising of the planet and of the Sun is the southward motion of the planet relative to the Sun. *Venus* passes about 1° 39′ north of the vernal equinox on the afternoon of April 26th. At 7 A.M. April 21st, Pacific time, it is in very close conjunction with *Saturn*, passing 0° 38′ north of the latter.

Mars rises at 1^h 36^m A.M. on March 1st, at 12^h 50^m A.M. on April 1st, and at 11^h 52^m P.M. on April 30th. During the two-months period it moves 31° eastward and 2° southward, from *Scorpio* through the southern extremity of *Ophiuchus* into *Sagittarius*, and during the latter part of April is in the neighborhood of the "milk-dipper" group in the latter constellation, a little farther north. Its distance from the Earth diminishes from 121 millions of miles on March 1st to 70 millions on April 30th, and its brightness at the latter date is consequently about three times as great as it was at the former, rather more than a magnitude, as the brightness of stars is usually reckoned. From now on it will be a conspicuous object until some months after opposition.

Jupiter is in fine position for evening observation. On March 1st it sets a little before 3 A.M. and on April 30th at a little before 11:30 P.M. It is in the constellation *Gemini*,

and moves about 7° nearly due eastward during the two months. It is in a region richer in bright stars than any other in the sky. *Castor and Pollux* are east of the planet, *Aldebaran* is west, and the bright stars of the *Orion* group, with *Canis major* and *Canis minor,* are to the south.

Saturn is an evening star on March 1st, but sets about half an hour after sunset, and is therefore too near the Sun for naked-eye observations. On the night of March 8-9th it passes conjunction with the Sun and becomes a morning star. The planet does not reach a great enough distance from the Sun to be seen in the morning twilight until well into April. At the end of the month it rises about an hour and three quarters before sunrise. It is in the constellation *Pisces,* and moves about 6° east and 3° north during the two months.

The phenomena displayed by *Saturn's* rings during 1907 will be of great interest to astronomers. The rings are so nearly edgewise to the Earth throughout the year that very little can be seen of them with a small telescope, but large telescopes may be able to show some new and interesting things. Since the autumn of 1891 both Sun and Earth have been above the plane of the rings, but on April 12th the Earth passes through this plane and from that time until July 25th the Earth and Sun are on opposite sides of the plane and the face turned toward us is the unilluminated face. On July 25th the plane of the rings passes through the Sun, and until October 4th both Sun and Earth are on the same side of the plane. On October 4th the Earth again passes through the plane, and for the remainder of the year the Earth and Sun are again on opposite sides. Early in 1908 the Earth again passes through the plane, and for the succeeding fifteen years the Earth and Sun are both below the plane. Questions as to the transparency and thickness of the rings may possibly be solved. The year 1907 affords the best opportunity for the study of these phenomena which we have had for many years. *Saturn* is in opposition in September, and the planet is fairly well placed for observation from the middle of April to the end of the year. In 1891 Sun and Earth were on opposite sides of the ring for only one month, and this period began only ten days after conjunction, so that the planet was too near the Sun for satisfactory observation.

Uranus rises shortly before 4 A.M. on March 1st and shortly

before midnight on April 30th. It is still in *Sagittarius* north of the "milk-dipper."

Neptune is in *Gemini*, a few degrees east of *Jupiter*.

THE CAUSE OF EARTHQUAKES AND MOUNTAIN FORMATION.[1]

By T. J. J. See.

Soon after the great earthquake of April 18th, the writer entered upon a general examination of the cause of earthquakes, because the explanations put forth to account for that phenomenon seemed inadequate. The conclusions finally reached have been embodied in a memoir just published in the *Proceedings* of the American Philosophical Society at Philadelphia: they had also been given in a public address at Leland Stanford Jr. University, on November 15th. The principal results are the following:—

(1) Volcanic activity, earthquakes, mountain formation, the feeble attraction of mountains noted in geodesy, the formation of plateaus and islands, and the great sea-waves which frequently accompany violent earthquakes, are all due to one common cause,—namely, the development of steam within or just beneath the Earth's crust, chiefly by the secular leakage of the ocean-bottoms, which are subjected to fluid pressure of nearly one thousand atmospheres by the superincumbent depth of water.

(2) As the development of steam is general under the seas, the strain under the Earth's crust would find relief chiefly around the margins of the oceans. The Pacific Ocean not only has high mountains all around it, but the land is rising geologically, and seven eighths of the active volcanoes of the world surround this great ocean. No active volcano is over about one hundred miles from the ocean or other large body of water, while many are submarine, and volcanic islands are forming all the time. Of the vapors emitted by volcanoes 999 in 1000 parts is steam, which again confirms the dependence

[1] Abstract of a lecture delivered before the A. S. P. in Hearst Hall, University of California, November 24, 1906.

on the sea inferred from the remarkable geographical distribution of these vents.

(3) Heretofore the mountains have been explained by the contraction and secular cooling of the Earth; but the explanation is very inadequate. Rev. O. FISHER has shown that the actual mountains are about one hundred times higher than this theory will account for, and this discrepancy can only indicate the unsoundness of the theory. In his paper on the rigidity of the heavenly bodies (*A. N.* 4104) the writer has shown that no currents circulate within the Earth, either now or at any time since the formation of the crust; the cooling has therefore been confined to the crust, and the secular shrinkage has been wholly insensible throughout all geological time. The mountains therefore have been formed by the sea, and not by the secular cooling of the Earth. This explains why the mountain chains are generally parallel to the seashore.

(4) Mountains, plateaus, and islands have all been upheaved by the injection of steam-saturated lava, which dries and becomes pumice, some of which is blown out of those mountains which become volcanoes. The mountains are underlaid with pumice, and hence their feeble attraction noticed in geodesy. Earthquakes are more general than volcanoes, which break out where the elevation of the land opens an outlet through the crust; as a rule, the volcanoes are near the centers of the earthquake belts, and always near the sea. In most world-shaking earthquakes lava is pushed under the land, from beneath the sea; hence the terrible shaking which is so destructive to life and property. In South America the land along the seacoast is frequently upraised; and a seismic sea-wave follows.

(5) The seismic sea-wave is due to the sinking of the sea-bottom, after its support has been weakened by the expulsion of lava under the adjacent coast. Hence after the earthquake the water drains away to fill up the depression, the currents meet in the center and raise a ridge, and when this collapses the great wave returns to the shore to add to the horrors of the earthquake. The Andes are pushed up along the coast, while the adjacent sea-bottom is sunk down into a trough. If the earthquake uplifts the coast, and thus forms mountains along the seashore, while the wave is due to the collapse of the sea-bottom, it is clear that the coast is being packed underneath

with lava, while the bed of the sea is being undermined by the expulsion of material to raise the mountains.

(6) During the great earthquake in Alaska, September 3-20, 1899, which has been most carefully investigated by Professor R. S. TARR and LAWRENCE MARTIN,[1] the uplift of the land at the maximum amounted to 47⅓ feet, while elevations of seven to twenty feet were common, though slight depressions also occurred in a few places. Professor H. D. CURTIS, of the D. O. Mills expedition of the Lick Observatory, reports from Santiago[2] that the harbor at Valparaiso was found to be ten feet shallower after the earthquake of August 16th. These observations give the key to the problem of earthquakes and mountain formation. The indications of nature are plain enough, if we will only follow her teachings and examine the evidence on its merits. The first duty of the investigator is to study for himself; important truth is not discovered without impartial judgment, labor, and thought.

The reader is referred to the paper in the *Proceedings* of the American Philosophical Society for further details of the complicated processes arising in earthquakes, mountain formation, and kindred phenomena.

NAVAL OBSERVATORY, MARE ISLAND, CAL.,
February 1, 1907.

[1] *Bulletin of the Geological Society of America*, May, 1906.
[2] Cf. *Argonaut* of November 2, 1906.

NOTES FROM PACIFIC COAST OBSERVATORIES.

NOTE ON MT. HAMILTON WEATHER.

The Lick Observatory is now passing through the most severe snow blockade that it has experienced at least since 1889-90. Between January 12th and 16th the snowfall exceeded fifty inches. The latter part of the fall was attended by considerable wind, and long stretches of the road were drifted full. The snowfall was remarkable for the low altitude to which it descended. At Smith Creek it amounted to eighteen inches, and the fall extended down to within one hundred or two hundred feet of the level of the Santa Clara Valley. No stage has reached the summit since January 12th, and at the date of writing, January 22d, we are not expecting the stage to come to the summit for another week at least. The wires which gave us telephone connection with the outside world were broken down under the great weight of snow and ice which collected on them. On two days we did not attempt to communicate with the stage, which ascended as far as Smith Creek. On other days the mails and supplies were carried up over the snow by members of the staff. Fortunately, no illness developed, and the inconvenience of the blockade has thus far not been serious.

The winter has been unusually cold, stormy, and cloudy. The precipitation to date corresponds to about twenty-one inches of rainfall.

W. W. CAMPBELL.

ON THE RELATION BETWEEN STELLAR SPECTRAL TYPES AND THE INTENSITIES OF CERTAIN LINES IN THE SPECTRA.[1]

During the past summer, in connection with the measurement of spectrograms obtained at the Mills Observatory in Chile by Professor WRIGHT, an investigation of the individual spectrum lines was begun, with a view of determining whether

[1] A more complete account of this investigation is published in *Lick Observatory Bulletin*, No. 106, and in *Astrophysical Journal*, Vol. 24, p. 333, 1906.

there is a shift of any of the lines which is progressive from spectral type to type. Several lines were found which undergo such a progressive change, as is indicated by the radial velocities obtained from them. An examination of ROWLAND'S tables shows that in most but not all cases studied lines apparently single are in reality blends of two or more close components. The nature of the variations found is such as to indicate varying intensities of the same components rather than the presence or absence of different components in the different types. It was the intention, when sufficient data had been obtained, to make comparisons with the enhanced and weakened lines in the spark and arc spectra. When a list of sun-spot lines[1] in the region covered by the Southern Mills plates became available, a comparison with these was made instead. The investigation was limited to stars of types F to Mb inclusive on the Harvard classification. In this classification the Sun is of type G.

The principal result of the comparison is the very strong indication that the physical conditions in the stars as we pass from the F to the Mb type vary in the same direction as from the Sun to the sun-spots. It is not intended to convey the impression, however, that any one type has been found in which the conditions are exactly the same as in the sun-spots, though an early K type is probably nearest to it. In the Mb type the relative intensities of the lines as shown, both by their appearance and their residuals, have gone far beyond what they are in the Sun, whereas in the F type they much precede the condition in the solar spectrum. ADAMS has shown a striking similarity to exist in the intensities of sun-spot lines and of the corresponding lines in the spectrum of *Arcturus* (type K), while HALE and ADAMS[2] have made a similar comparison of intensities for *α Orionis* (type Ma) in the region λ 5393 to λ 5703.

A large number of lines might be mentioned which change greatly in intensity and appearance as we proceed from the F to the Mb type, this change being frequently very prominent even from the G to the K type, and which are not included in ADAMS'S list of lines affected in sun-spots. Among the most

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[1] "Sun-spot Lines in the Spectrum of *Arcturus*," by WALTER S. ADAMS, *Astrophysical Journal*, Vol. 24, p. 69, 1906.

[2] *Astrophysical Journal*, Vol. 23, p. 400, 1906.

striking of these are the Cr lines, λ 4254.5 and λ 4274.9, which become very strong, wide, and diffuse as we follow the scale of stellar types. A few cases of contradictory evidence have also been found, in which the residuals show a decided shift in the opposite direction from that which would be expected from the intensities assigned to the components in sun-spots. Among these the line λ 4435.2 may be especially mentioned. For this blend both my value of the wave-length, as determined from the spectrograms, and the progressive trend of the residuals indicate a shift of its center toward the violet instead of toward the red. Some of the observed differences between sun-spots and stellar K type, in which the physical conditions may be similar, may be due to the fact that in the stars this condition is the average condition in their entire atmospheres, while in the case of the sun-spots some effects may be altered by overlying layers of gases and vapors or by other local circumstances. Nevertheless the similarities are sufficiently striking to promise much for this line of study. The results here given depend not only upon the appearances of the lines, but primarily upon quantitative measurements of their positions.

It was thought possible that for variable stars of large light changes traces of velocity variations of some of the lines might be found, corresponding to small changes in spectral type as the stars varied from maxima to minima and *vice versa*. In the case of *o Ceti* actual changes in the character of the spectrum are well-established facts, though up to the present no appreciable changes in the wave-lengths of any of its spectrum lines have been observed—leaving out of account the large displacements of the bright hydrogen lines. A comparison of the available measures of *η Aquilæ*, a variable star of the fourth class with a range of only 0.8 of a magnitude in light variation, showed evidences of variations in the positions of some of its lines from light maximum to minimum similar to the variations that were found from type to type. A further study of this variable star is desirable to establish definitely the exact character and amount of these variations.

The following few examples are typical of the progressive variations that were found for the different types. The intensities in the Sun are ROWLAND'S, and those in sun-spots and in *Arcturus* are taken from ADAMS'S article (*l. c.*).

λ 4352.908 Fe—Intensity in Sun, 4 } In sun-spots, 6-7; in *Arcturus*, 7-8;
53.044 V —Intensity in Sun, 0 } widened toward red.

Residuals (in km.):—

F	F8G and F8G Pec.	G	G5K	K		K2M and K5M	Mb
−3.0	−3.7	+0.8	−0.7	+1.6	+2.1	+3.6	+3.4
	+1.5	+1.0	−0.6	+3.1	+3.4	+3.0	+4.9
	−1.0	+1.7	+2.2	+0.8	+2.6	+3.0	+4.6
	+1.5	−1.1	+2.8	+1.4	+1.4	+1.0	+4.7
	−3.5		±0.0	+2.6	+4.8	+3.9	+3.9
			+1.7	+3.1	+2.2	+2.2	+6.5
				+1.5	+0.8	+4.4	
				+2.2	−0.2	+3.3	
				+0.8	+4.3	+3.0	
				+2.0	+1.9		
				+0.9	+3.2		
					+3.6		
Means:							
.....	−1.0		+0.8	+2.2		+3.0	+4.7

λ 4468.663 Ti—Intensity in Sun, 5; in sun-spots, 4-5; in *Arcturus*, not affected.

Residuals:—

F	F8G	G	G5K	K		K5M	Mb
−1.3	−2.2	−0.3	+1.4	+2.8	+2.7	+5.7	+6.8
−4.1	−0.3	−1.5	+0.9	+2.6	+3.7	+0.8	+7.0
+1.7	−2.9	−0.9	−0.7	+3.9	+4.3	+6.3	+3.5
−3.0	−0.9		−0.9	+1.1	+1.5	+2.5	+6.1
−3.7	+1.4		+2.7	+1.0	−0.3	+4.7	+4.8
			−2.1	+0.6	+1.9	+4.7	+1.9
				+2.2	+0.6	+4.7	+1.7
				+0.4	+0.4	+5.2	+5.9
				−0.4	−1.5		
				+1.2	−3.0		
				+1.3	+3.3		
				+0.7	−0.1		
Means:							
−2.1	−1.0	−0.9	+0.2	+1.3		+4.3	+4.7

λ 4314.964 Ti—Intensity in Sun, 1 }
15.138 Ti—Intensity in Sun, 3 } Not included in list of sun-spot lines.
15.262 Fe—Intensity in Sun, 4 }

Residuals:—

	F	G	K	K5M	Mb
Means:	+1.1	−1.4	−2.0	−2.7	−5.0

λ 4435.129 Ca—Intensity in Sun, 5; in sun-spots, 6 }
.32 Fe—Intensity in Sun, 2; in sun-spots, not affected. } In *Arcturus*, 8.

Residuals:—

	F	F8G and G	G5K and K	K5M	Mb
Means:	−4.0	−1.7	+0.3	+2.5 ±	+1.8 ±

The establishing of these variations in the wave-lengths of some of the lines with spectral type will make necessary the exercise of great care in the selection of lines in radial velocity determinations, and a proper allowance for the type.

MT. HAMILTON, December 14, 1906. SEBASTIAN ALBRECHT.

HONORS CONFERRED UPON PROFESSORS AITKEN AND HUSSEY.

The Paris Academy of Sciences has conferred the Lalande Prize for 1906 upon Professor R. G. AITKEN, of the Lick Observatory, and Professor W. J. HUSSEY, formerly of the Lick Observatory, and now Director of the Detroit Observatory at Ann Arbor. The prize usually consists of a gold medal and a small sum of money. It has on several occasions been divided between two astronomers, as in the present case.

The following paragraphs are translated from the report of the award published in *Comptes Rendus* for December 17, 1906:—

"No branch of sidereal astronomy presents to-day a higher interest than that relating to the study of double or multiple stars.

"Among contemporary astronomers who have undertaken this study with success, Messrs. R. G. AITKEN and WILLIAM J. HUSSEY,[1] astronomers in the Lick Observatory, are in the first rank, because they have each discovered more than 1,200 new doubles;[2] and in almost three fourths of these pairs the distance of the components is less than two seconds of arc.

"These astronomers have, moreover, measured with care all these pairs in such a manner as to fix the present relative positions of the components.

"In addition, they have made observations upon the fainter satellites of *Jupiter, Saturn,* etc.

"These are results of the highest importance, and the Commission proposes to divide the Lalande Prize between Messrs. R. G. AITKEN and W. J. HUSSEY.

"The conclusions of this report are adopted by the Academy."

W. W. CAMPBELL.

MT. HAMILTON, January 22, 1907.

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[1] Professor HUSSEY has recently left the Lick Observatory, in order to become Director of the Detroit Observatory of the University of Michigan.—*Comptes Rendus.*

[2] The number 1,200 refers necessarily to those published. Professor AITKEN, up to 1907, has discovered more than 1,500 double stars, and Professor HUSSEY had discovered more than 1,300 up to the time of his departure in June, 1905.—W. W. C.

THE ORBIT OF HO 212 = 13 CETI.[1]

In number 104 of these *Publications* a note on this interesting binary system will be found giving my measures in 1905, which indicated a revolution period of about 7½ years. Measures made in 1906 confirm this conclusion, the companion-star being now within a few degrees of the position it occupied in 1899.

Using Dr. SEE's measure in 1899 and my own made in the following years (the only ones known to me), I have derived the set of elements here given. They satisfy the observations on which they were based within the probable error of measure, and also satisfy the two early measures by HOUGH in 1886 and 1887.

It is now certain that 13 *Ceti* has a shorter period than any other known visual binary except δ *Equulei*. A well-defined proper motion adds to the interest of the system.

ELEMENTS.

$P = 7.42$ years.	$\omega = 51^\circ.75$
$T = 1905.28$	$\Omega = 50\ .40$
$e = 0.74$	$i = \pm\ 48^\circ.05$
$a = 0''.214$	Angles increasing.

January 24, 1907.

R. G. AITKEN.

NOTE ON COMET *h* 1906 (METCALF).

This comet was discovered near opposition by Rev. J. H. METCALF, of Taunton, Mass., from a photograph taken November 14, 1906. The discovery position is $\alpha = 4^h\ 4^m\ 35^s$, $\delta = -2^\circ\ 15'.8$.

No preliminary elements were computed here for either this comet or Comet Thiele, which was discovered at about the same time, as the observatory force was crippled by the illness of Mr. EINARSON, Assistant in Astronomy, so that no time was available for computing.

Later, however, two sets of elements based upon longer arcs were derived, and the results have been published in *Lick Observatory Bulletin* No. 108. The first set is based upon FATH's observations of November 17th, 25th, and December 5th. It was found that no parabola could be passed through

[1] A more detailed account is given in *Lick Observatory Bulletin*, No. 110.

these positions. They are represented, however, by an elliptic orbit in which the comet has a period of 6.9 years.

An observation by Dr. AITKEN, made December 18th, is not very closely represented by these elements. It was therefore decided to correct them by means of this observation. The resulting second set is also elliptic, giving a period of 8.2 years. The plane of the orbit is inclined nearly 15° to the plane of the ecliptic. The comet made its nearest approach to the Sun, 150 millions miles, October 5th. It is a new member of *Jupiter's* family of comets.

At the time of discovery it was very faint and was receding from both the Earth and the Sun. At present it can be seen in only the largest telescopes, its brilliancy being less than one fourth of what it was at discovery.

RUSSELL TRACY CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT,
January 18, 1907.

GENERAL NOTES.

Stellar Photometry.—Publication No. 33 of the Carnegie Institution of Washington, "Researches in Stellar Photometry," by JOHN A. PARKHURST, Instructor in Practical Astronomy in the University of Chicago, was issued during November of the year just closed. The quarto volume of 192 pages contains observations and discussions of twelve variable stars of long period observed by Mr. PARKHURST between 1893 and 1905. During the first seven years the observations were made mostly at Marengo, Illinois, with a 6-inch Newtonian reflector by BRASHEAR. Since 1900 Mr. PARKHURST has been connected with the Yerkes Observatory, and the 12- and 40-inch refractors of that institution were used in addition to the 6-inch reflector. During the first period the observations were made visually by the method of ARGELANDER, but during the second period a wedge photometer, devised by Professor E. C. PICKERING, was used for the most part.

In the introduction the author states that his work is addressed to the solution of four problems in photometry, and the statement of these is admirably prefaced as follows:—

"The problems of stellar photometry are closely connected with many cosmic questions, primarily with the light changes of variable stars; but they have an equally important bearing on the questions of stellar distribution and evolution. It has been said by good authorities that it is of more importance to measure the light than the place of a star, and if one considers merely the astonishing number of variable stars now being discovered, it will be admitted that the importance of stellar photometry can scarcely be overestimated. The material here submitted is the natural outgrowth of the writer's variable-star work, the plans being extended as the instrumental and other facilities were improved.

"The following contribution is offered toward the solution of several photometric problems, among them being:—

"(1) The accurate determination of complete light-curves of twelve variable stars of long period, having faint minima.

"(2) The question of behavior of variable stars during their faint stages which can only be observed with the largest apertures.

"(3) The adaptation of the Pickering 'equalizing wedge photometer' to the determinations of magnitudes.

"(4) The photometric measurement of very faint magnitudes, and their relation to estimates founded on the limit of visibility of different apertures of telescopes."

Under the headings "Essentials for good visual comparisons" and "Essentials for good photometer measures," Mr. PARKHURST gives also in the introduction some very wholesome advice which it would be well for all variable-star observers to read.

Chapter I is devoted to a description of the instruments used, and especially to the consideration of the constants of the equalizing wedge photometer.

The following twelve chapters are devoted one each to the twelve variable stars observed,—T *Andromedæ*, V *Andromedæ*, W *Andromedæ*, R *Comæ*, RU *Herculis*, RV *Herculis*, S *Lyræ*, S *Cygni*, SX *Cygni*, V *Delphini*, Z *Cassiopeiæ*, Y *Cassiopeiæ*. These are for the most part new variables discovered during the last decade of the nineteenth century. Each chapter contains a short historical statement; a photograph of the field of the variable made with a 24-inch reflector; various tables giving the individual observations, the comparison-stars, constants for reduction, observed maxima and minima, etc.; the magnitude-curve; the light-curve; the mean light-curve; and conclusions giving period of star and peculiarities of its light-curve. The observations and reductions have been made with minute care and great thoroughness, and it is evident from the tests applied that the results obtained by Mr. PARKHURST are possessed of a high degree of precision.

The magnitudes of the stars observed lie between 7.5 and 17, the greatest range of any one variable, V *Delphini*, being nine magnitudes, from 8 to 17, a really remarkable range. The only other variable having an observed range of more than 7.5 magnitudes being χ *Cygni*, 4.5 to 13.5. The average range for the twelve stars is 5.8 magnitudes. The periods of these lie between 259 and 529 days, the average being 362 days. A large number of long-period variables have periods approximately a year in length, and the average period is over three hundred days and apparently approaching closer to a year. It seems hardly likely, however, that these facts have any special significance.

It is well known that in stars of this class the increase in light is accomplished in less time than the decrease, the ratio between the two parts of the period being about five to six. This feature is well shown in the light-curves of all the twelve stars observed by PARKHURST, except S *Cygni*, for which

M — m is almost exactly one half the period. The inequality between increase and decrease of light is greatest for V *Delphini*, the ratio being about five to eight. Its period is 529 days, one of the longest known. This star shows, then, three distinctive characteristics among the twelve stars, its period is the longest, its range is the greatest, and the inequality between the two parts of the period is the largest.

The elements obtained by the author for the twelve stars are derived from observations of ninety-five maxima and ninety-three minima. The observations, however, were not confined to the epochs of maxima and minima, but were carried on, as far as possible, over the whole period, and the special feature of the volume is the well-determined mean light-curves which have been derived in each case. It is now generally recognized among variable-star investigators that it is just as essential to determine the *form* of the light-curve as to determine the length of the period. Several good series of variable-star observations from which light-curves may be deduced have been published without graphic representation of the curves, and the usefulness of the investigations considerably decreased thereby.

In the concluding chapter there is given, among other things, a comparison between the theoretical and the observed limits of vision of the three telescopes employed in the investigations. The theoretical limits were computed by the use of POGSON'S well-known formula and the agreements are remarkably close. The seventeenth magnitude is the limit of the giant 40-inch refractor.

It is to be hoped that Mr. PARKHURST may be able to continue in this line of work, for investigations such as these, planned with care, executed with skill, discussed with precision, are most urgently needed in variable-star astronomy.

S. D. T.

Double-Star Orbits.—By his long-continued devotion to the study of double stars and by the quality of the many orbits he has published, Dr. W. DOBERCK has well earned his position as one of the leading authorities in this branch of astronomy. That his interest does not diminish with the years is evident from the number of his investigations that have recently appeared. The latest (*Astronomische Nachrichten*, 4144-4145) are new orbits of three of the best known of the

binary systems,—namely, *ζ Cancri*, *ω Leonis*, and Σ 3062 = H I 39.

There are other recent orbits of all three of these systems that represent the observed motion up to the present time with a high degree of accuracy, and it is perhaps questionable whether so much labor as is represented by these new discussions was wisely bestowed. Nevertheless it is always interesting and instructive to compare the results obtained by different computors, using different methods of solution, especially when, as in the case of the three stars named, the orbits are based substantially on the same material. The periods of the three systems, according to DOBERCK, are 116, 105, and 60 years respectively, and the motion is not specially rapid at the present time in any one of them. The new elements of *ω Leonis* and Σ 3062 do not differ materially from the other recent orbits, and only serve as additional evidence that our knowledge of the motions in these systems is now fairly accurate.

In the case of *ζ Cancri*, Dr. DOBERCK's results differ more from SEELIGER's than might be expected, in view of the fact that the latter represent recent observations within the probable error of measure.

The two sets of elements are as follows:—

	P.	T.	e	a	ω	Ω	i
SEELIGER:	59^y.11	1868.11	0.381	0″.858	250°.26	80°.19	11°.14
DOBERCK:	60 .08	1870.65	0.339	0 .856	183 .65	.....[1]	0 .00

Angles decreasing.

If one might venture any criticism upon such painstaking work as Dr. DOBERCK'S, it would be on the ground that he does not make much use of the measures of distance, basing his results almost exclusively upon the angle measures. The question might also be raised whether elaborate least-squares solutions are justified by the quality of the material available, but this question will be answered in due time by the way in which the results thus derived represent the future motions in these systems. A.

On Star Streaming.—At a meeting of the British Association for the Advancement of Science held at Cape Town, South Africa, August 17, 1905, Professor J. C. KAPTEYN read a paper with the above title. It cointained an announcement of

[1] The planes of the true and of the apparent orbit coincide in this solution.

the results of a study of the proper motions of over 2,400 stars observed by BRADLEY.

The study was taken up for the information it was expected to yield regarding the motion of the Sun among the stars, but certain anomalies appeared which seemed to indicate the existence of an important and hitherto unsuspected systematic motion among the stars under investigation. It appeared that the proper motions showed a trend toward two points in the sky about 140° apart, lying south of α *Orionis* and η *Sagittarii* respectively.

The explanation offered is that a large number of stars distributed throughout all of the regions of the sky covered by the Bradley catalogue partake of a common, or group, motion peculiar to themselves. All of the stars under investigation seemed to belong to one or the other of two groups.

This introduces a complication into the problem of determining the apex and velocity of the Sun's way, and Professor KAPTEYN desires confirmation from spectroscopic observations before proceeding to the completion of his study.

A subsequent study by Mr. A. S. EDDINGTON of the proper motions of the stars contained in the Groombridge catalogue has quantitatively confirmed Professor KAPTEYN's conclusion. The 4,500 stars of the Groombridge catalogue include a much larger proportion of faint stars than the Bradley list, and they lie within a smaller area of the sky, all being within 52° of the North Pole. Mr. EDDINGTON concludes that the two-drift hypothesis is a good first approximation to the actual state of affairs, but he is by no means convinced that there may not be other drifts involving a sufficiently large number of stars, and so distributed that account will have to be taken of them in the solution of the problem of determining the Sun's motion among the stars. An abstract of Mr. EDDINGTON's paper may be found in *Observatory* No. 377. N.

Algol Variable RR Draconis.—In *Bulletin* No. 9 of the Laws Observatory of the University of Missouri Professor SEARES presents the results of photometric observations of an interesting new variable of the *Algol* type, RR *Draconis.* The period is found to be 2.831079 days. At normal brightness the variable is of the tenth magnitude, and the decrease in brightness at the time of minimum is over three magnitudes. The

exact amount of decrease could not be determined with the telescope employed, for the star was invisible for a period of about two hours in the neighborhood of the minimum. The time occupied in the light changes is about ten hours. The rate of change of light at the steepest part of the curve is over a magnitude in half an hour.

This star at minimum is fainter than any other *Algol* variable listed in the Harvard Provisional Catalogue of Variable Stars. Its range of brightness is also greater than that of any other variable of this type, the average range being 1.4 magnitudes.
S. D. T.

National Academy of Sciences.—The autumn meeting of the National Academy of Sciences was held November 20th, 21st, and 22d in the buildings of the Harvard Medical School, Boston. Among the large number of papers presented five were upon astronomical subjects, as follows: "The Work of the Bruce Telescope," by S. I. BAILEY, of Harvard University; "Present State of Knowledge as to Motions of the Terrestrial Pole," by S. C. CHANDLER, Editor of the *Astronomical Journal*; "Extent and Structure of the Stellar System," by G. C. COMSTOCK, of the University of Wisconsin; "Sun-Spot Spectra, and Their Bearing on Stellar Evolution," by G. E. HALE, of the Solar Observatory of the Carnegie Institution; "Planetary Inversion and the Tenth Satellite of *Saturn*," by W. H. PICKERING, of Harvard University.

At the *conversazione* held in connection with the meeting, photographs, slides, and drawings were presented by the Harvard College Observatory and by the Solar Observatory of the Carnegie Institution.

The following notes have been taken from recent numbers of *Science*:—

Professor CHARLES LANE POOR, of Columbia University, gave a public lecture under the auspices of the New York Academy of Sciences and the American Museum of Natural History, on November 19th, on "The Proposed New Astronomical Observatory and Nautical Museum for New York City."

Dr. WILLIAM H. BROOKS, Director of Smith Observatory and Professor of Astronomy at Hobert College, Geneva, N. Y.,

has received a medal from the Astronomical Society of Mexico for his discoveries of twenty-five comets.

Professor RAJNA, of Bologna, is making an appeal for funds to rebuild the observatory there on a new site, and to provide it with instruments suited to modern requirements.

Professor ERNEST W. BROWN, who goes at the end of the present academic year from Haverford College to Yale University, has been awarded the gold medal for 1907 by the Royal Astronomical Society for his work on the movements of the Moon.

Mr. SYDNEY S. HOUGH, chief assistant in the Royal Observatory, Cape of Good Hope, has been appointed His Majesty's Astronomer at that observatory on the retirement of Sir DAVID GILL.

Dr. SIDNEY DEAN TOWNLEY, astronomer in charge of the International Latitude Observatory at Ukiah, California, and lecturer in astronomy in the University of California, has been appointed to an assistant professorship in the department of applied mathematics at Leland Stanford Junior University. Dr. TOWNLEY will assume the duties of his new position with the beginning of the next academic year in August.

NEW PUBLICATIONS.

ANDOYER, A. Cours d'astronomie. Première partie: Astronomie théorique. Paris: Hermann. 1906.

GIBBS, J. W. The scientific papers of. New York: Longmans, Green & Co. 1906. 2 vols., royal 8vo.

HILL, G. W. The collected mathematical works of. 3 vols. Washington: Carnegie Institution. 1906. $2.50 per vol.

LOWELL, P. *Mars* and its canals. New York: Macmillan Co. 1906. 8vo. 15 + 393 pp. Cloth, $2.50.

MORSE, E. L. *Mars* and its mystery. Boston: Little, Brown & Co., 1906. 8vo. viii + 192 pp. Cloth, $2.00.

MOULTON, F. R. An introduction to astronomy. New York: Macmillan Co. 1906. 8vo. 18 + 557 pp. Cloth, $1.25.

MOULTON, F. R. A class of periodic solutions of the problem of three bodies with applications to the lunar theory. Reprint from Trans. Am. Math. Society. 1906. 40 pp.

NEWCOMB, S. A compendium of spherical astronomy. New York: Macmillan Co. 1906. 8vo. 18 + 444 pp. Cloth, $3.00.

Optical convention, 1905: Catalogue of optical and general scientific instruments. Edinburgh: F. & E. Murray. 1906.

PARKHURST, J. A. Researches in stellar photometry. Washington: Carnegie Institution (Publ. No. 33). 1906. 4to. 192 pp. Paper, $2.00.

Science Year Book, The. Diary, directory, biography, and scientific summary for 1907. London: 27 Chauncy Lane. 1906. 5s.

SEARES, F. H. The *Algol* variable RR *Draconis*. Columbia: University of Missouri. (Laws Observatory Bulletin No. 9.) 4to. 15 pp.

VERSCHAFFEL, M. L'ABBÉ. Observations faites au cercle méridien en 1904. Abbadia: Observations. Tome IV. 4to. 190–.

Athens: Annales de l'observatoire national. Tome IV. 1906.

Transactions of the international union for co-operation in solar research. Vol. I. London: Sherratt & Hughes. 1906. 8vo. xii + 257 pp. Cloth.

Minutes of the Meeting of the Board of Directors held at the Students' Observatory, Berkeley, on January 26, 1907, at 7:30 P. M.

President Leuschner presided. A quorum was present. The minutes of the last meeting were approved.

The following new members were duly elected:—

List of Members Elected January 26, 1907.

Mr. Charles H. Crossland............8 Forsythe St., Chelsea, Mass.
Mr. Curtis H. Thomas...............Traer, Iowa.

It was upon motion,

Resolved, That the Committee on Publication be authorized to reprint number 2 of the *Publications* in an edition of 250 copies.

Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific held at the Students' Observatory at Berkeley on January 26, 1907, at 8 P. M.

President Leuschner called the meeting to order, and introduced the lecturer of the evening, Professor W. W. Campbell, Director of the Lick Observatory, who read his paper on "The Solar Corona," illustrating his remarks by a number of lantern-slides.

A committee to nominate a list of eleven Directors and Committee on Publication, of three members, to be voted for at the Annual Meeting to be held on March 30, 1907, was appointed as follows: Messrs. J. K. Moffitt (Chairman), S. D. Townley, C. D. Perrine, J. D. Galloway, O. von Geldern.

A committee to audit the accounts of the Treasurer and to report at the Annual Meeting in March, was appointed as follows: Messrs. Chas. S. Cushing (Chairman), Daniel Suter, B. A. Baird.

Adjourned.

OFFICERS OF THE SOCIETY.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 806 Franklin Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 806 Franklin Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," 806 Franklin Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

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PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XIX. SAN FRANCISCO, CALIFORNIA, APRIL 10, 1907. No. 113.

PRELIMINARY STATISTICS ON THE ECCENTRICITIES OF COMET ORBITS.[1]

By A. O. LEUSCHNER.

Various investigations of the eccentricities of the orbits of comets have led to the conclusion that the majority of such orbits are parabolic. In fact, about three fourths of all comet orbits have been found consistent with an eccentricity equal to unity. This is the main reason why it is generally accepted that a comet orbit is parabolic, unless it can be shown to be otherwise.

An accurate knowledge of the eccentricities of comet orbits is of importance in determining the origin of comets. It is, therefore, advisable to study the eccentricities from as many points of view as possible. Two methods of classifying the eccentricities have occurred to me which do not seem to have entered into the analysis hitherto. Both are related to the accuracy of the observational material from which the orbits are derived. One is to classify the eccentricities on the basis of the general accuracy of the observations, the other on the basis of the observed heliocentric arc.

Marked progress has been made during the last century in the methods of observation and in the construction of telescopes, so that observations have become more and more reliable, and the number of days during which comets of the same brightness may be followed has constantly increased.

Ever since the first computation of a comet orbit was made, it has been customary to derive a parabola as a first approximation to the orbit, and to attempt a more general solution only if the deviations of the observed positions from the places com-

[1] Abstract of address of the retiring President of the Society, presented at the annual meeting, March 30, 1907.

puted from the most probable parabola were in excess of the probable errors of observation. This custom has become so thoroughly fixed in astronomy that even now it would be considered absolutely unwarranted to suspect a comet of moving in an ellipse if by a little stretching of the probable limits of observational error a parabola could be found to represent the observed positions.

A prejudice has always existed, and exists now, in favor of the parabola. This prejudice is not entirely due to statistical investigations of the orbits of past comets. A further excuse for the same may be found in the fact that the first geometrical and analytical methods for solving a comet orbit were parabolic. The solution of an elliptic orbit was originally possible only in cases like HALLEY'S comet, where more than one appearance had been observed, so that one of the unknowns, the period, became known.

GAUSS'S general solution had its first application on the asteroid *Ceres*, at the dawn of the nineteenth century, and it was not until some time later that general methods were also applied to comets.

It is a well-recognized fact that when the observed arc is short and the probable error of observation on a comet is large, the solution of the orbit will be uncertain, or, in other words, in such cases a large number of different orbits will be found to satisfy the observations. The "Short Method" which has been used extensively in the Berkeley Astronomical Department during the last three years is well suited for estimating the limiting values of the elements. The range of possible periods and eccentricities is far greater than has perhaps been supposed hitherto. A cursory examination of many definitive orbits based on normal places formed from long series of observations shows that in many cases a long-period ellipse will often answer as well as a parabola. The ellipse is then generally dismissed with the statement that there is no reason to suspect a deviation from the parabola. It would be just as consistent to conclude that there is no reason to suspect that the comet moves exactly in a parabola. In accordance with existing belief regarding the eccentricities of comet orbits, Dr. KREUTZ in his biennial reports to the Astronomische Gesellschaft adopts the parabola whenever it is found sufficient.

Before proceeding to an examination of the published lists

of elements it is therefore well to emphasize that possibly in no case where an ellipse or hyperbola alone is given can the observations be represented by a parabola, but when a parabola is given the observations may frequently be consistent with an ellipse and sometimes with a hyperbola.

If, in spite of this fact, it can be demonstrated that by far the majority of well-determined orbits is elliptic, then the time has come when astronomers should abandon their prejudice for the parabola, by investigating and stating the complete range of possible solutions in each case.

OLBER'S, GALLE'S, and WINLOCK'S lists were not available when a preliminary examination of the eccentricities was undertaken. The excellent list, however, contained in E. WEISS'S edition of "Littrow, Wunder des Himmels," is well suited for the purpose of the preliminary investigation, especially because it gives the duration of visibility in days. This list runs to 1885. The results of the preliminary examination were, however, roughly revised just before publication on the basis of GALLE'S and WINLOCK'S lists and KREUTZ'S biennial reports to the Astronomische Gesellschaft to 1904, which latter are contained in the *Vierteljahrsschrift*. Comets discovered between 1885 and 1895 were added to WEISS'S list only when the duration of visibility was included in the data at hand. Periodic comets are, of course, counted only for their first apparition.

For the purpose of classifying the orbits on the basis of the general accuracy of the observational material, or more nearly of the observed positions, the percentage of parabolic orbits was ascertained for each of three groups, in the order of time as given in Table I.

TABLE I.

Dates.	$e - 1$
–1755	99 per cent
1756–1845	74 per cent
1846–1895	54 per cent

It is safe to assume that there has been a progressive and pronounced advance in the accuracy of observation in these three periods of time. Hyperbolic orbits were not included in the totals on which the percentages of Tables I and II are based. From the more accurate observations of the fifty years from 1846 to 1895 we may therefore conclude that it is no more probable that a comet is parabolic than that it is not.

In Table II the eccentricities have been grouped on the basis of the duration of visibility in days. The percentage of parabolas is given for each group. The comets discovered before 1756 have been excluded in the totals from which these percentages were derived, as their orbits can throw little light on the question under consideration.

TABLE II.

Duration of Visibility.	e = 1
1– 99 days	68 per cent
100–239 days	55 per cent
240–511 days	13 per cent

These figures are certainly striking. They show that the longer a comet is under observation the more probable it becomes that its orbit cannot be satisfied by a parabola.

This result is in entire accordance with the opinion held by some astronomers that few, if any, orbits are strictly parabolic. In the last group only eight comets were available, which are all given as elliptic by WEISS, and for one of these KREUTZ's later reports give a parabola, which has been adopted, the same as every orbit has been considered parabolic in these tables for which the observations could be satisfied by a parabola. It is therefore extremely doubtful whether a parabola is definitely established for any comet having remained visible 240 days or more. It would have been better if Table II could have been based on the length of the observed heliocentric arcs, but these are not immediately available, and in a first approximation for a large number of comets the average of the number of days of visibility may be taken to correspond to the average heliocentric arc.

Percentages have also been derived for various ranges of eccentricity. These, however, will not be published until the final investigation has been concluded.

The average eccentricity of periodic orbits is very high. In applying the short method it has been found that whenever a short arc yielded a considerable range of periodic solutions, a longer arc would yield solutions for the eccentricity nearer the upper than the lower previous limits. The explanation of the high eccentricities lies in the nature of things. Long-period comets cannot come within the range of visibility from the Earth unless their orbits are highly eccentric. The

others must remain invisible, until the power of our telescopes is still further increased.

From the average brightness of comets at unit geocentric distance the maximum perihelion distance at which a comet may be seen in opposition from the Earth with the more powerful instruments may be derived. The values of the eccentricity corresponding to this maximum for a given value of the semi-major axis or period will then be the minimum eccentricity which the orbit of a comet of average brightness and of given period must have in order to be visible from the Earth, under the most favorable circumstances.

This question will be studied in connection with a proposed further study of comet orbits. The theory that, in general, comets are permanent members of our solar system seems to have been greatly strengthened by the foregoing preliminary statistics. It will be remembered that until KEELER began photographing nebulæ with the Crossley reflector the spiral was considered the exceptional form of a nebula. The percentage of double stars is increasing so rapidly that their discovery either directly, or spectroscopically, or photometrically, or otherwise, is no longer a cause for surprise. It seems eminently probable that with further investigation of cometary orbits the parabola will be found to be the exception.

BERKELEY ASTRONOMICAL DEPARTMENT, March 30, 1907.

THE SOLAR CORONA.[1]

BY W. W. CAMPBELL.

Of all the wonders of this and other worlds that it has been my good fortune to see, a total solar eclipse is by far the most impressive, and the Sun's corona is its central and most beautiful feature. The corona appears to have attracted the attention of intelligent observers who dwelt within the shadow-paths, in all ages of our civilization. PLUTARCH has left an excellent description of its appearance, and occasional later

[1] Lecture delivered before the Astronomical Society of the Pacific on January 28, 1907. The lantern slide illustrations are necessarily omitted.

writers have referred to it. Speculation as to what the corona really is was naturally very meager prior to the middle of the last century, for the custom of dispatching expeditions to study eclipse phenomena had not been inaugurated, and it therefore seldom fell to the lot of any one man to observe two eclipses, either with or without scientific instruments and methods.

In KEPLER'S day, and until less than a century ago, the corona was believed by most men of science to be due to the illumination of the Moon's atmosphere. When it was finally established that the Moon has extremely little or no atmosphere, the corona was generally explained as a phenomenon of the Earth's atmosphere; and it was not until the year 1870 that the tide of scientific opinion turned toward the Sun itself as the origin and center of the corona. Even as late as 1883, one of the ablest of astronomical physicists published an admirable discussion of the corona as a purely subjective, non-material phenomenon, due to the diffraction of the Sun's photospheric rays at the Moon's edge. The objective existence and solar character of the corona are to-day thoroughly established, and the erroneous views of our predecessors come as a surprise no doubt to many persons of the younger generation. It is far otherwise with those who are familiar with eclipse history. Take away the spectroscopic method of study, which came nominally in 1859, but virtually, for eclipse purposes, later in the sixties, and take away the photographic plate which was made to bear upon the problem, faintly in the early seventies and strongly in the eighties,—take these away, and I think we should still be struggling with the question, Where is the corona situated? Let two of us make a pencil drawing of the same corona,—one of us in Spain and the other in Egypt. The two drawings will be more remarkable for their differences than for their agreements; and what is more natural than to attribute these differences to varying conditions in the terrestrial atmosphere above the two observers, or to the changed influence of the irregularities on the Moon's edge as viewed from the two points of observation. Let the eclipse observer of to-day try to find out something new about the corona, *even with* the spectroscope, polariscope, thermoscope, and photographic plate, and his respect for the pioneers will be established upon a firm basis.

The corona remains a strictly eclipse phenomenon. The

commendable efforts of several leading astronomers to observe the corona in full sunlight have unfortunately failed, on account of its relative faintness and its low effective temperature, and all the methods now available seem hopelessly unpromising. Given suitable appliances, such as the 40-foot eclipse camera designed by Professor SCHAEBERLE, the corona may be seen faintly and imperfectly during one to three minutes before totality is complete, and during an equal interval after totality ends; but we have not been able to make any scientific use of these pre- and post-totality views. Every item in our knowledge of the corona has been obtained during the total phase. Assuming that observable total eclipses occur, on the average, once in two years, and that their average duration is three minutes, no astronomer, in fifty years of activity in following the Sun and Moon, can hope to utilize more than seventy-five minutes in eclipse observation. Making the reasonable deduction of one third for clouds and other deterring factors, his maximum expectation during a long life must not exceed fifty minutes. The total duration of observable eclipses for any one observer since the spectroscope and photographic plate have been available scarcely equals a half-hour. Herein lies the chief difficulty of coronal investigation. However, the progress made since the spectroscope showed a bright coronal line, in 1869, and photographic plates at two stations showed identical coronal structures, in 1871, has been so great as to be unique in science.

Another difficulty in coronal study is for the most part only vaguely appreciated. The coronal streamers are on the whole radial, with reference to the Sun, and appear to overlie every part of the Sun's spherical surface. Now, every coronal structure lying within the cylinder occulted by the Moon is entirely hidden from view, and all structure lying outside of this cylinder is seen in projection upon one plane. The projected image of the corona recorded on the photographic plate is complex to an apparently hopeless degree. Every small area in the apparent inner corona is a composite of all the structures lying betwen the observer and the area in question. The tops of streamers pointing nearly toward and nearly away from the observer, the intermediate parts of numerous other streamers, and the bases of streamers nearly at right-angles to the observer's line of sight are all projected upon a common

area. And similarly for all parts of the coronal image. There is no known way of resolving the composite image into its elements.

Notwithstanding these and other difficulties, we know much concerning the properties and characteristics of the corona. However, this knowledge has not reached the deductive stage. Our facts are isolated ones. We are not only not able to predict the detailed form of a future corona, but we cannot say why an observed corona has a certain general form. We know so little concerning the origin of the corona and its dependence upon the rest of the Sun, that starting *de novo* with our present-day knowledge of the main body of the Sun, and no knowledge whatever of the corona, we should be more surprised by the existence of a corona than by its total absence!

Taking up first the study of coronal images, it has been established that there is a dependence of coronal forms upon the sun-spot period. At and near sun-spot maximum the general outline of the corona is circular. The polar streamers are as extensive and as brilliant as the equatorial streamers. That this is true of the outer regions of the corona as well as of the inner is shown by both long and short photographic exposures. At or near sun-spot minimum the general form is very different. The polar streamers are short, faint, delicate, and few. The equatorial streamers, and especially those in the sun-spot zones or at slightly higher latitudes, are longer than at maximum, and in general there are two broad streamers extending easterly and two westerly from the Sun, several solar diameters in length. These are necessarily but the projections of two sets of long streamers entirely encircling the Sun. Their bases seem to be situated a little further from the equator than are the sun-spot zones. These variations in coronal forms with spot activity are now so well established that coronal streamers and spots may safely be said to have a closely related origin.

The hooded forms of the inner corona, each covering a conspicuous prominence, can leave no doubt that they and the prominences concerned have had a closely related origin.

The great conical disturbance in the corona of 1901, noted by Dr. PERRINE, whose vertex was shown by him to be situated immediately over or very near to the great and only spot on the Sun at the time, can leave little doubt that the disturbed

coronal structure and the photospheric disturbance indicated by the spot had a common origin.

All the evidence is to the effect that the corona is closely related to the rest of the Sun. We do not know the nature of this relation; but we can safely say that a thorough understanding of the Sun requires an understanding of the corona.

The light radiated by the corona appears to be of three kinds:—

1st. A thin and very irregular stratum, perhaps never exceeding 200,000 miles, and more probably never exceeding 100,000 miles, in depth, lying at the base of the corona and apparently resting upon the chromosphere, gives a bright-line spectrum. The natural interpretation of this spectrum is that the stratum giving rise to it consists of a gas or vapor heated to incandescence; but it has been suggested here and there that the bright lines may indicate an electric glow in the inner corona, such as one gets from a Plücker tube agitated by an electric current. For my part, there seems to be no real necessity for going beyond simple incandescence produced by the Sun's heat. The element yielding the ten or twelve bright lines[1] has not been identified with any terrestrial substance. There may indeed be more than one vapor or gas present.

It is difficult to conceive how irregular masses of vapor can maintain themselves at great heights above the solar surface, in opposition to the Sun's gravitational attraction. Perhaps the vapor is constantly given off by the solid or liquid particles which seem to form the major part of the inner corona, for these particles must be at a high temperature, under the influence of the Sun's heat.

2d. Nearly all of the light from the inner corona—perhaps ninety-five per cent of it—appears to give a strictly continuous spectrum, which indicates a solid or liquid source raised to incandescence. The most reasonable conclusion is that the inner corona consists largely of minute particles maintained at a very high temperature by the adjacent body of the Sun.

3d. The light of the middle and outer corona yields a spectrum which seems to be substantially identical with the solar spectrum—a spectrum containing the usual Fraunhofer dark lines. On this point there is not unanimity of observers. PLUVINEL in 1893 and the Crocker Expedition of 1901 to

[1] DYSON gives a list of twenty-four corona lines.—*Phil. Trans.*, Vol. 206, p. 451, 1906.

Sumatra and of 1905 to Spain have recorded dark lines, whereas others appear to have observed continuous spectrum, pure and simple. The discordance is difficult to explain. If the dark lines exist, we have every reason to believe that the corresponding parts of the corona consist of minute particles of matter, not shining appreciably by their own light, but principally by virtue of original sunlight which radiates to the particles and is reflected and diffracted to us.

The latter view is supported overwhelmingly by a long series of polarization observations. Granted that the corona is composed of minute particles which diffuse the sunlight falling upon them, the coronal light should be polarized, radially, very much as sunlight diffused by our own atmosphere is polarized strongly in planes passing through the Sun. It is true that polarization may be produced otherwise than by reflection or diffusion,—for example, by a magnetic field, as in the Zeeman effect; but polarization seems to exist in all parts of the corona.

The opinions of astronomers as to the materials composing the corona, and as to why the Sun has any corona at all, have been very divergent. Some have believed that the corona is composed of meteors, many of them revolving around the Sun, and others falling into the Sun. However, this theory is largely in disfavor, and we need not consider it, though no doubt there are a great many meteors both revolving around and falling into the Sun.

SCHAEBERLE's mechanical theory proposes that "the theoretical corona is caused by light emitted and reflected from streams of matter ejected from the Sun by forces which in general act along lines normal to the surface of the Sun, these forces being most active near the center of each sun-spot zone." To account for the longer streamers in the corona, considering their materials to be ejected by forces analogous to volcanic forces and to be drawn back by the Sun's gravitational power, would require that their speeds on leaving the Sun should be between 200 and 400 miles per second. According to this theory, also, there would be multitudes of both ascending and descending particles.

According to BIGELOW's magnetic theory, the corona is a sort of solar aurora whose streamers occupy positions corresponding to the lines of force in the Sun's magnetic field, just as the Earth's magnetic field seems to control the streamers of terrestrial auroras.

When LEBEDEW, and NICHOLS and HULL, some five or six years ago, proved experimentally that light and heat radiations exert a pressure upon all bodies in their paths, it occurred to ARRHENIUS, and possibly to others, that here is the basis for a satisfactory theory of the corona. If strong radiations press upon exceedingly minute particles, the particles will move away from the source of radiation; the larger and denser particles, speaking popularly, will travel slowly, and the lighter and smaller particles rapidly. There can be little doubt that matter exists at the Sun's surface in a state capable of being acted upon effectively by this radiation pressure. According to this theory, the smaller and lighter particles (more exactly, those having the smallest product of mass and density) would be driven off into distant space, with little chance of returning to the Sun; and the reuniting of two or more particles would in many cases give gravity the advantage, so as to bring them back to the Sun. It is true that this theory, in common with all the others, leaves much to be explained. For example, it is difficult to say why sun-spot inactivity should produce extraordinarily long streamers in the high sun-spot latitudes, and sun-spot activity streamers of equal lengths all over the Sun.

I think there is an excellent chance that all these theories have much truth in them. There can be no question that eruptive forces, or convection and evection currents of great speed, exist at the Sun's surface,—responsible for many of the prominences, certainly,—and perhaps they give an outward impulse to the coronal material. The forms of many coronal streamers certainly resemble closely the lines of force in a magnetic field, and we cannot doubt that radiation pressure must be active and effective. But it is scarcely conceivable that the eruptive forces on the Sun can give speeds of 300 or 400 miles per second to the ejected coronal materials, and the radiation-pressure theory renders the supposition of such great speeds unnecessary.

At the eclipse of 1900, ABBOT made one of the most important of recent eclipse observations, in that he measured the heat radiation of the inner corona. He found that the corona is effectively cooler than the instrument with which he observed. The observation was a delicate one and liable to considerable error. Although confirmation is very urgently desired, ABBOT's observation is probably approximately cor-

rect. ABBOT concluded that the corona appears "neither to reflect much light from the Sun nor chiefly by virtue of a high temperature to give light of its own, but seems rather to be giving light in a manner not associated with a high temperature. . . ." This conclusion seemed at first to deny the theory of the corona's constitution outlined above, as based upon the evidence of the spectroscope and polariscope; but a very illuminating paper by ARRHENIUS has, I think, shown that ABBOT's results on the heat of the corona are in harmony with the view that the inner corona consists mainly of incandescent particles.

ARRHENIUS has determined from computation that coronal particles in the region observed by ABBOT must have a temperature of about 4,300° C. (8,000° F.), assuming the effective temperature of the Sun's photosphere to be 6,000° C.; and, therefore, these particles must be radiating light by virtue of their own incandescence. These particles are so few and so far apart that the effective temperature observed by the bolometer is not at all the temperature of the particles themselves, but is, so to speak, the average temperature for the incandescent particles and the cold background of space upon which these particles are seen here and there in projection. The total area of the background covered by the particles in projection is an exceedingly minute fraction of the whole area. The spectroscopic and thermometric observations are harmonized within the limits of error of observation by assuming that, in the part of the corona observed, there is but one minute dust-particle for each fifteen cubic yards of space.

We should not overlook the fact that the series of incandescent points in the distant corona affect the eye or the photographic plate just as if they formed a continuous and highly illuminated surface, whereas the thermometer in effect averages the radiations from the coronal particles to the instrument and the radiations from the instrument to the cold background of space. The action of our atmosphere in stopping a certain proportion of the heat radiations is also effective and has to be taken into account.

The existence of matter in the corona at great distances from the Sun implies that it has come from somewhere—doubtless from the Sun itself. This necessarily implies that motion has occurred. Is the material of the corona moving

out from the Sun or toward the Sun, or both, or neither? We have no accurate observational knowledge on this subject. The unusually favorable eclipse of August 30, 1905, offered a hope that large-scale photographs of the corona secured in Labrador, Spain, and Egypt, or in two of these countries, would enable us to detect changes in the coronal structure occurring between the instants of totality in those countries. Dr. PERRINE and I have made careful comparisons of the coronal images recorded by the Crocker Eclipse Expeditions in Spain and Egypt. A number of fairly well-defined nuclei of the corona existed both east and west of the Sun. As a result of these comparisons we are able to say that there is no certain evidence of motion having occurred in the interval of 70 minutes which elapsed between the instants of totality in Spain and Egypt. Details of structure within the nuclei have suffered change, but the mass as a whole cannot have moved so much as one mile per second during the interval. Greater speeds might well have occurred in the principal coronal streamers without our having detected them; for their structure is uniform and regular, and well-defined nuclei are absent. Thus, in the cases where high speeds should perhaps be most naturally expected, photographic plates have little power to record them.

Measures of motions of approach and recession within the corona by means of the spectrograph are unpromising, for several reasons. The coronal light is intrinsically weak, and exposures are from necessity short. The brighter parts of the corona radiate light forming a continuous spectrum, neglecting the almost insignificant component which gives rise to bright lines. Even if spectrograms of the middle and outer coronal regions could be secured with the Fraunhofer lines recorded in good strength, their interpretation would be difficult and somewhat unpromising. The slit of the spectrograph would receive light from streamers which radiate in a variety of directions from the Sun. There would be streamers pointing both toward and away from the observer and streamers occupying positions of all values intermediate between these limits. If the coronal particles were moving outward exclusively, the general effect would be to cause a shift corresponding to recession, but the lines would be broadened. Particles moving toward the Sun would in effect displace in the direction

of approach, at the same time broadening the lines. It will be easy for the reader to determine the effect of a motion of either kind in a streamer making a given angle with the observer's line of sight, and space will not be taken here to summarize further the general effect. It is evident that a dark-line spectrum, if one of sufficient density and dispersion could be obtained, would be of great complexity. However, a knowledge of the motions within the corona would doubtless be our most effective power in determining the origin of the corona, and the subject should not be abandoned as hopeless.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1907.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter..	May	4,	1^h 53^m P.M.	Last Quarter..	June	2,	9^h 20^m P.M.
New Moon....	"	12,	12 59 A.M.	New Moon....	"	10,	3 50 P.M.
First Quarter..	"	20,	5 27 A.M.	First Quarter..	"	18,	6 55 P.M.
Full Moon....	"	27,	6 18 A.M.	Full Moon....	"	25,	1 27 P.M.

The summer solstice, the time when the Sun stops moving north and begins to move south, occurs June 22d, 6 A.M., Pacific time.

Mercury is a morning star on May 1st, rising less than an hour before sunrise, and is therefore too near the Sun for naked-eye observation. It moves rapidly toward the Sun, and passes superior conjunction, becoming an evening star, on the night of May 23d-24th. It then moves rapidly away from the Sun and a little northward. Shortly after June 1st it remains above the horizon an hour after sunset, and this period increases to about an hour and three quarters soon after the middle of the month. It then begins to shorten, but does not go below an hour and one half until after the close of the month. Greatest east elongation (25° 29′) is reached on June 27th. This is not quite the maximum possible, but is not much below it. The month of June this year therefore

gives about the best opportunity for naked-eye views of *Mercury*.

Venus remains a morning star, rising 1^h 20^m before sunrise on May 1st, and this interval remains about the same throughout the two-month period, even increasing a little toward the end of the period, although the apparent distance between planet and Sun is diminishing, the distance apart of the two bodies being 8° less at the end of the period than it was at the beginning. Although the planet is very low down until nearly the time of sunrise, its brightness is so great that there will be no difficulty in seeing it during the early twilight.

Mars rises shortly before midnight on May 1st, before 10^h 30^m on June 1st, and before 8^h 30^m on June 30th. It moves eastward about 7° until June 5th, and from that time until the end of the month it moves westward about 4°. It remains in *Sagittarius,* north of the "milk-dipper" group. Its distance diminishes from sixty-nine millions of miles on May 1st, to fifty millions on June 1st, and thirty-nine millions on June 30th. At the last date its distance is only about one million miles greater than the minimum, which will be reached early in July. The planet will still gain materially in brightness all through the period, and will practically have attained its maximum at the end of June. It will then be about as bright as Jupiter. *Mars* will come to opposition on July 6th, and its nearest approach to the Earth will occur a few days later, the least distance being a little less than thirty-eight millions of miles. This is the most favorable opposition since that of 1892, which came on August 3d. The planet was then two and one-half millions of miles nearer the Earth than it will be during the present opposition,—not a great difference, but noticeable. The next opposition will come toward the end of September, 1909. This will be rather more favorable than the present one. The most favorable time is when opposition and perihelion come at about the same time. This happens when opposition occurs near the end of August. The present opposition occurs eighty-two days before time of perihelion; that of 1909 will occur about half of that time after perihelion. The sidereal period of *Mars* remains practically constant (687 days), somewhat less than two years. This is the time from one perihelion to the next. The synodic period, or time from opposition to opposition, averages 780

days, somewhat over two years, but is subject to considerable variation, about fifty days, the longest period coming when opposition occurs near time of perihelion. From the last opposition to the present one the interval is 788 days, and the next period will be considerably longer. The cause is the eccentricity of *Mars's* orbit, and the consequent variability in the velocity of the planet.

Jupiter sets shortly before $11^h\ 30^m$ P.M. on May 1st, and shortly after 8^h P.M. on June 30th. It moves eastward about 13° in the constellation *Gemini* and at the close of the period is nearly due south of *Castor* and *Pollux*, the principal stars of the constellation. It is in conjunction with *Mercury* on June 15th, the latter passing 1° 41′ to the north.

Saturn is a morning object, rising somewhat less than two hours before sunrise on May 1st, at $1^h\ 26^m$ A.M. on June 1st, and at $11^h\ 35^m$ P.M. on June 30th. It moves about 3° eastward and 2° northward in the constellation *Pisces*, and at the end of June is only about 2° distant from the point marking the vernal equinox. The rings are practically out of sight during May and June, as the Earth and Sun are on opposite sides of the plane. Large telescopes may show the edge illuminated, and possibly light may pass through small gaps in the rings. A better opportunity for seeing the same phenomenon will come during the autumn, when Earth and Sun will have changed places relative to the rings.

Uranus rises shortly before midnight on May 1st, and shortly before 8^h P.M. on June 30th. It is still in the constellation *Sagittarius* and moves westward about 2° during the two months. It is in conjunction with *Mars* on May 1st, which passes between it and the "milk-dipper" group at a distance of 0° 46′ from *Uranus*.

Neptune is in *Gemini* not far from *Jupiter*. The time of nearest approach is May 21st. *Jupiter* then passes 1° north of *Neptune*.

(FIFTY-SIXTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Dr. A. KOPFF, astronomer, Heidelberg,

Germany, for his discovery of an unexpected comet on August 22, 1906.

Committee of the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
C. D. PERRINE.

SAN FRANCISCO, March 20, 1907.

(FIFTY-SEVENTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Professor H. THIELE, astronomer, Copenhagen, Denmark, for his discovery of an unexpected comet on November 20, 1906.

Committee on the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
C. D. PERRINE.

SAN FRANCISCO, March 20, 1907.

(FIFTY-EIGHTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to J. H. METCALF, astronomer, Taunton, Massachusetts, for his discovery of an unexpected comet on November 14, 1906.

Committee of the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
C. D. PERRINE.

SAN FRANCISCO, March 20, 1907.

LIBRARY NOTICE.

Members who had in their possession at the time of the San Francisco fire any books or pamphlets belonging to the Library of the Astronomical Society of the Pacific are requested to send them to the Librarian of the Society, R. T. CRAWFORD, Students' Observatory, Berkeley, Cal.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Note on Comet Holmes.

Search was made for Comet Holmes with the 36-inch telescope on several nights before its rediscovery by photography by Professor Wolf, on August 28, 1906, and also on several nights in September. The conditions were fairly good, and an object as bright as 15th magnitude ought to have been detected, but the comet was not seen.

According to the corrections to Zwiers's ephemeris given by the photographic observations, the comet's place was certainly examined, and it is therefore safe to conclude that its visual magnitude was below 15.

Poor seeing on moonless nights in late October, when the comet reached its maximum theoretical brightness, and in the following months, prevented further search.

March, 1907. R. G. Aitken.

A Simple Method of Computing the Lengths of Slender Uneclipsed Solar Crescents.

In a note on the contact times of the total solar eclipse of 1898 Professor Campbell called attention to the fact that the times as computed from the data of the different ephemerides were not as consistent as might be wished, but in the case of that eclipse, as well as with earlier ones, there seems to be no evidence of a systematic variation of the observed from the computed times. For the eclipse of May 28, 1900, the preliminary report of the Lick Observatory–Crocker Eclipse Expedition to Georgia shows a difference of some seven or eight seconds between the computed and observed times of second contact. At the eclipse of August 30, 1905, the discrepancy was found to be greater. The Lick Observatory party reported a difference of seventeen seconds for second contact and twenty-three for third, while other observers also found that totality occurred about twenty seconds earlier

than predicted. The difference is understood to be due to the increasing error of the Moon tables at present in use.

To obtain a very approximate time for the beginning of totality which shall be practically independent of the error of the lunar tables, the interval before the beginning of totality that the uneclipsed crescent of the Sun subtends a definite angle at the Sun's center may be computed. A number of observers have used this method, and Dr. DOWNING has computed these data for the eclipse of January 3, 1908. In addition to the times of contact computed in the ordinary way, he gives the times before the commencement of totality corresponding to cusp angles 90°, 60°, 45°, 30°, and 15°. A note on the method used here in recomputing these values might not be without interest to eclipse observers.

The ordinary eclipse formulæ give us the following:—

$d =$ Duration of totality.

P_2 and $P_3 =$ Points of contact II and III, with their position-angles from the E–W line.

Let $a =$ semi-diameter of Sun in seconds of arc, and $b =$ semi-diameter of Moon in seconds of arc, corrected for augmentation. Draw the E–W and N–S lines through O, the center of the Sun.

Then, if C_2 and C_3 are the positions of the Moon's center at contacts II and III, they will lie on $P_2\,O$ produced and $P_3\,O$ produced, respectively, each at a distance $b = a$ seconds from O. A line drawn through C_2 and C_3 will be the path of the Moon's center relative to O, and the distance $C_2\,C_3$ will be traversed in d seconds of time. The velocity of the Moon's motion in seconds of arc per second of time is therefore $\frac{C_2\,C_3}{d}$. This velocity is readily obtained, since in the triangle $O\,C_2\,C_3$, the sides $O\,C_2$ and $O\,C_3$ are known, and the angle at O is the supplement of the sum of the position-angles.

Suppose the Moon's center at L when the semi-angle at the Sun's center subtending the arc joining the cusps of the uneclipsed crescent is α. Draw $L\,M$ and $O\,M$ to one of the cusps, and also $L\,O$, which bisects the angle subtending the cusps.

From the triangle $L\,O\,M$, $L\,O$ may now be computed, having which, the triangle $L\,C_2\,O$ is solved for $L\,C_2$. This is the

distance over which the Moon's center must move before beginning of totality, and the velocity being known, the time is also determined.

G. B. Blair.

March, 1907.

Increased Water Supply on Mt. Hamilton.

The following description of a new pumping plant at Mt. Hamilton is published for its possible interest to other mountain observatories.

Up to the present time the Lick Observatory has obtained its water supply from a small spring (Aquarius) in the north cañon, located about one mile northeast and 325 feet lower than the observatory buildings. The flow from this spring exceeded the consumption in the late winter and early spring months and fell far short of the consumption in the summer and fall months. The storage and distributing reservoirs on Kepler Peak, one half mile east and fifty feet higher than the buildings, supplied the deficiency during the dry season. The needs of the observatory for household and photographic purposes were met by this system, provided the rainfall for the year had been normal and constant care was taken to guard against leaks in the system. In seasons when the rainfall fell below the normal, it was necessary to use the water under short-allowance rules. This has occurred four or five times during the history of the observatory and has been a serious matter, especially as the system of fire protection was impaired just at the time of the year when it was most needed.

Plans were formed two years ago to increase the water supply, based upon the use of a spring in the south cañon, which is 300 feet lower than Aquarius, but whose flow is at least fifteenfold greater than that of Aquarius.

The system of pumping is a somewhat novel one, and I am under great obligations to Mr. J. A. Lighthipe, head of the Engineering Department of the General Electric Company in this district, for calling my attention to it.

The spring is 680 feet lower than the Kepler reservoirs, and the distance between the two, measured on the thirty-degree slope, is 1,400 feet. Catchment reservoirs, capacity 12,000 gallons, have been established at the spring. A two-inch power and supply pipe leads from these reservoirs farther down the steep cañon, a distance of 700 feet on the slope, and

215 feet in altitude. At this lower level an hydraulic motor pump is installed. This is constructed very much like an ordinary steam pump, except that the steam cylinders are replaced by water cylinders, forming the motor. The pipe last described divides into two branches just above the pump. One of these connects with the motor end of the pump and the other with the pumping end. The piston areas for the two motor cylinders are sixfold greater than the areas of the pumping pistons. The large motor pistons, operated by six gallons of water with 215 feet head, enable the small pumping pistons to lift one gallon through the 2,100 feet of two-inch pipe to the Kepler reservoirs, 895 feet in altitude above the pump. In other words, the pump places one gallon in seven in the Kepler reservoirs, the other six gallons doing the work. The simple device of dividing the power pipe just above the pump so as to supply water to the pump-end under a pressure of 215 feet, increases the efficiency of the pumping system to this extent.

The only personal attention required by the pump consists in filling the oil cups once a week. The pump was constructed by the Dow Pumping Engine Works, San Francisco, under the guarantee that it would do the work described.

At the present time the pump is delivering 6,200 gallons per day to the Kepler reservoirs. Our average daily consumption throughout the year is about 1,700 gallons. It is expected that one gallon in seven during the late summer and fall months will deliver about 1,200 gallons per day. With the 200,000 gallons stored in the Kepler reservoirs, and with the Aquarius pumping system available in case of need, it is believed that our annual anxiety as to the water supply will be eliminated. During the dry season the available water supply will be three- or fourfold greater than it has been in the past.

An electric pumping plant is replacing the steam plant at Aquarius.

W. W. CAMPBELL.

MT. HAMILTON, March 25, 1907.

NOTE ON COMET *a* 1907 (GIACOBINI).

The first comet of this year was discovered close to opposition, March 9th, by GIACOBINI, at Nice. From the first three available observations (March 9th, by GIACOBINI, at Nice; March 11th, by RICE, at Washington; March 12th, by FATH,

at Mt. Hamilton) a preliminary orbit was computed. The elements and ephemeris are given in *Lick Observatory Bulletin*, No. 111.

Dr. AITKEN states that "the comet as seen here on the first date was very small, round, with well-marked condensation, and almost equal to an eleventh-magnitude star in brightness." It is now receding from the Earth.

The observations are satisfied by a parabola. The comet has a retrograde motion, the plane of its orbit having an inclination of 142° to the ecliptic. Its nearest approach to the Sun was on March 12th, at which time it was 190,000,000 miles, or 2.05 astronomical units from it. The longitude of perihelion is 50°; the longitude of the ascending node is 96°.

Having no later observations from the East, and not having one from Mt. Hamilton because of the position of the Moon and the continual rain in California, it has been so far impossible to obtain a second orbit.

STURLA EINARSON.
ESTELLE GLANCY.

BERKELEY ASTRONOMICAL DEPARTMENT, March 27, 1907.

NOTE ON COMET *b* 1906 (KOPFF).

This comet was discovered in March, 1906, by KOPFF, at Heidelberg. Its geocentric motion was very small. From a twenty-two-day arc a set of parabolic elements was computed by Mr. CHAMPREUX and myself and published with an ephemeris in *Lick Observatory Bulletin*, No. 97. The remarkable feature of the orbit is the great perihelion distance, 3.3 astronomical units. Because of its great distance from the Sun its heliocentric motion in the last year has been but 50°. The Earth has therefore overtaken the comet, and it was picked up again March 21st of this year by KOPFF. The residuals for this place from our orbit are (O–C) $\Delta\alpha = -0^{\circ}.6$; $\Delta\delta = +0^{\circ}.1$. A change of about eight days in the time of perihelion passage will remove the greatest part of these. No attempt will be made to improve these elements on the basis of this year's observation since Professor WEISS has found and published in *A. N.* 4154 a set of elements and ephemeris which represent this place almost exactly. WEISS's elements have been deduced from observations extending from January, 1905, to May, 1906. The position of January, 1905, is from a

photographic plate by Professor WOLF, found after the comet had been discovered by KOPFF. More than 800 days have elapsed since this observation of January, 1905, so that, excepting the periodic comets, this comet holds the record for length of time during which it has been under observation. It is further highly probable that it will be picked up when the Earth overtakes it again next year.

RUSSELL TRACY CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT, March 30, 1907.

THE PROMOTION OF DR. AITKEN.

It gives me great pleasure to announce that Dr. R. G. AITKEN has been promoted to the position of Astronomer in the Lick Observatory. It is unnecessary to say that this action on the part of the President and Regents of the University is thoroughly deserved. It would be difficult to speak too highly of Dr. AITKEN'S scientific researches. His work on double stars is certainly unsurpassed in quantity, quality, system, and breadth of view.

W. W. CAMPBELL.

PROMOTION OF PROFESSOR LEUSCHNER.

The promotion of Dr. A. O. LEUSCHNER, Director of the Students' Observatory, from Associate Professor to Professor of Astronomy is another well-earned event which it gives us pleasure to record. Professor LEUSCHNER has built up one of the strongest and best of astronomical schools; and although his teaching, and administrative duties both inside and outside of his department, have been heavy, he has found time to make valuable investigations and to encourage and direct similar investigations by the assistants in his department. The publication of Professor LEUSCHNER'S work on the Watson asteroids is awaited with interest.

W. W. CAMPBELL.

REPORTS OF OBSERVATORIES.[1]

CHAMBERLIN OBSERVATORY, DENVER, COLORADO.

The work of the Chamberlin Observatory during 1906 was nfined to observations of comets, the installation of some new pparatus, and some special studies in personal equation.

H. A. HOWE, *Director*.

INTERNATIONAL LATITUDE OBSERVATORY, UKIAH, CALIFORNIA.

The programme of the International Geodetic Association for observing variations of latitude was changed at the beginning of 1906 by dropping the twenty-four refraction pairs (pairs which culminate at large zenith-distances, about 60°), and also six of the latitude pairs, and substituting for these new latitude pairs. The observing-list now consists of ninety-six pairs, distributed throughout the twenty-four hours of right ascension, sixty-six of which belong to the old list and thirty of which are new. All of the stars culminate at zenith-distances of less than 26°.

Observations continued throughout 1906 without serious interruption from any cause. The weather was favorable during all months except February, March, and December, a monthly total of less than 150 pairs being considered unfavorable. The three longest intervals without observations were fourteen nights in August, eight nights in January, and six nights in each of February, November, and December. The first of these was caused by the absence of the observer and the others by unfavorable weather. The rainfall for the year was 51.8 inches. The maximum temperature was 108° F., on July 24th; the minimum temperature 22°, on November 24th, 28th, 29th.

The following table gives a summary of the observations made for the variation of latitude. The first column contains the number of determinations made each month, the second column the number of nights upon which observations were made, the third column the number of complete nights (sixteen determinations), the fourth column the greatest interval in each month during which no observations were obtained.

[1] Arranged alphabetically according to name.

1906.	Pairs.	Nights.	Nights.	Nights.
January	175	13	8	8
February	114	10	5	6
March	138	11	7	5
April	203	14	11	5
May	180	13	9	5
June	220	18	12	3
July	247	16	15	5
August	224	14	14	14
September	263	17	16	3
October	238	17	14	4
November	212	15	11	6
December	144	12	7	6
Totals	2,358	170	129	
Means	196.5	14	11	6

Definitive reductions of all the observations for the variation of latitude (233) obtained between April 4th and May 4th, both inclusive, were made in order to determine if possible whether or not there was an appreciable shift in the Earth's crust at Ukiah at the time of the earthquake of April 18th. No sudden change in the latitude was found. The results of the computations were printed in these *Publications* (vol. XVIII, p. 241).

SIDNEY D. TOWNLEY, *Astronomer-in-Charge.*

LICK OBSERVATORY, MT. HAMILTON, CALIFORNIA.

The scientific work of the Lick Observatory during the calendar year 1906 was pursued by each member of the staff with his accustomed industry and enthusiasm. It related for the most part to advancing the solution of the greater problems upon which we have been engaged in past years, and only here and there were minor or new problems taken up.

Professor TUCKER, with the aid of Mr. R. F. SANFORD, Carnegie Assistant, has completed the extensive reductions of his meridian-circle observations of 2,800 zodiacal stars, and the manuscript results are nearly ready for publication. The purpose of these observations is to provide more accurate reference-points in the zodiac as a basis for securing improved orbits of the planets.

Mr. TUCKER continued throughout the year the observation of a carefully constructed programme of stars, for the purpose

of securing a system of star places of the highest accuracy, which shall be strictly *fundamental*, as opposed to basing observations upon a system established with other instruments. There is need in these observations for the most accurate clock that can be secured, and a Riefler constant-pressure clock, with nickel-steel pendulum, was installed late in 1906.

A special list of stars, used by Professor DOOLITTLE, of the University of Pennsylvania, in a study of terrestrial latitude variations, has also been observed by Mr. TUCKER.

Out of 965 photographs of the minor planet *Eros*, made at the favorable opposition of 1900, 525 have been selected as a basis for improving our knowledge of the Sun's distance from the Earth. Excellent progress in the measurement and reduction of these photographs has been made by Miss CHASE and Miss HOBE, Carnegie Assistants, under the supervision of Dr. PERRINE. Another year should see the work well along toward completion. There will be nothing of special interest to communicate to general readers until all the measures are combined in a final solution for the most probable value of the Sun's distance.

Good progress has been made in the study of the eclipse photographs of 1905, obtained by the Crocker Expeditions to Spain and Egypt.

Mr. PERRINE has made a careful examination of the photographs secured in Spain and Egypt for the intramercurial-planet search. The Spanish plates record stars in the region examined down to about the eighth photographic magnitude, but all of the images observed on the plates have been identified as those of well-known stars. Assuming that the planet would be one magnitude fainter photographically than visually, the search may be said to prove that no planet as bright as the seventh magnitude exists within the region searched. This includes an area about 9° by 29° lying along the direction of the Sun's equator.

It will be remembered that similar search made at the Sumatra eclipse of 1901 by Mr. PERRINE was limited in one third of the area to stars brighter than the sixth photographic magnitude. The Spanish results are thus an extension and advance of those secured in Sumatra. It is becoming more apparent that the anomalous motion of *Mercury's* perihelion must seek an explanation elsewhere than in the attractions of

intramercurial planets. A paper published very recently by Professor SEELIGER makes it extremely probable that the hitherto unexplained anomalies in the motions of the four inner planets are due to the attractions of the widely distributed materials responsible for the zodiacal light. It is unfortunate that clouds limited the observations in Sumatra and Spain. The cameras employed are capable of recording tenth-magnitude stars with clear skies and exposures of three minutes or less. It is hoped that an eclipse of the near future will enable this limit to be reached and thus give completeness to the observational programme.

The unusually favorable eclipse of 1905 afforded a hope that large-scale photographs of the corona secured in Labrador, Spain, and Egypt, or in two of these countries, would enable us to detect changes in the coronal structure occurring between the instants of totality in those countries. Dr. PERRINE and I have made careful comparisons of the photographs secured in Spain and Egypt. A number of well-defined nuclei existed both east and west of the Sun. Details of structure within the nuclei suffered change, but the masses as a whole appeared to remain in fixed positions. We are able to say that those masses could not have moved so much as one mile per second during the interval of seventy minutes which elapsed between the totalities in Spain and Egypt. Greater speeds might well have occurred in the principal coronal streamers without our having detected them; for their structure is uniform and regular, and well-defined nuclei are absent. Thus, in the cases where high speeds should perhaps be most expected, the photographic method has little power to detect them.

In connection with the Sumatra eclipse, Mr. PERRINE was able to reach the interesting conclusion that a large disturbed volume of the corona, conical in form, appeared to be situated exactly over the large and only sun-spot visible during several days preceding and following the eclipse. A very similar disturbed volume is shown on the coronal photographs of 1905. The vertex of the cone does not appear to be over one of the large spots then existing on the Sun, but it is above a large region of the photosphere which shows many signs of disturbance.

The complete reduction of the time and longitude observations in Spain confirms definitely the conclusion reached on

eclipse day,—that mid-totality occurred twenty seconds earlier than the time predicted by the nautical almanacs.

It is hoped that the spectrographic and polarigraphic results will be ready for publication within the coming year.

The D. O. Mills Expedition to Chile terminated its first period of activity on March 1, 1906. At that time Dr. CURTIS assumed charge for the second period of five years, in succession to Professor WRIGHT, who returned to California shortly thereafter. The working programme of the original expedition called for spectrograms of all the brighter stars south of declination $-25°$ which should contain lines capable of accurate measurement, down to photographic magnitude 5.5. The stars so selected formed a list of 143. Four spectrograms were obtained of practically every star on the list, and additional ones of many others were taken for special purposes. Eight hundred spectrograms in all were obtained. The half of these were definitively measured and reduced by January, 1907, and it is expected that the results from the other plates will be ready by the middle of the present calendar year.

I am inclined to ascribe great importance to this programme of work, now nearing completion in accordance with plans which have been definitely held in mind since 1894. There is a tremendous demand for the knowledge of the velocities of the stars determined spectrographically, for use (*a*) in determining the motion of the solar system as a whole, and (*b*) in determining the structure of the sidereal universe. Observations of this kind either have been made or are under way at ten northern-hemisphere observatories. The southern two sevenths of the sky, out of reach of northern instruments, must be observed in the same manner before a satisfactory solution of these problems can be hoped for, and before the observations of the northern stars can assume their full value. Up to 1906 existing southern-hemisphere observatories have published spectrographic velocities of but two or three stars. The Mills Expedition was organized to secure observations of the brighter stars with special reference to their use in problem *a*.

In the erection of the observatory on Cerro San Cristobal, Santiago, during the rainy season, in meeting and overcoming difficulties as they arose, and in carrying out the programme of observation as planned within the estimated time, Acting-

Astronomer WILLIAM H. WRIGHT, in charge of the expedition, is entitled to great credit.

The dearth of southern-hemisphere observations of the exact kinds that the Mills Observatory is fitted to supply made it extremely desirable that our station should continue in active existence. When the subject was presented to Mr. MILLS, he was pleased to provide for its liberal support through a further period of five years, and for many improvements and additions to the instrumental equipment. Dr. CURTIS, in charge of the expedition during its second term, is assisted by Mr. GEORGE PADDOCK, formerly of the University of Virginia.

The determinations of the radial velocities of the stars on Mt. Hamilton by means of the Mills spectrograph attached to the 36-inch equatorial made good progress during the year 1906. About 400 spectrograms were secured, principally by Messrs. CAMPBELL, MOORE, and WRIGHT. The stars observed were, on the average, fainter than in former years. This involved longer exposures, and resulted in a slightly reduced number. A considerably larger number of spectrograms taken in 1906 and former years were measured and reduced definitively, principally by Messrs. MOORE, BURNS, and NEWKIRK.

Professor AITKEN'S programme of double-star observations with the 12-inch and 36-inch refractors has two main purposes: (*a*) to examine systematically all the stars to the ninth magnitude inclusive between the North Pole and —22° of declination, checking the positions of all previously known double stars and noting all additional pairs that are under five seconds in distance, as the basis for a thorough statistical study of double stars; and (*b*) to measure regularly all known double stars showing motions of revolution, especially the more rapid and difficult pairs, to provide data for improving our knowledge of their orbits.

Approximately, 300 new pairs were discovered in the year. Seventy-five per cent of them are under two seconds of arc. This work involved careful examination of 10,000 stars, in round numbers. The total number of new stars discovered by Messrs. AITKEN and HUSSEY, who co-operated in organizing and prosecuting this double-star survey, is about 2,900. Given reasonably good winter skies, the programme for the northern hemisphere should be completed by Dr. AITKEN within three years.

The second part of Dr. AITKEN'S programme is thoroughly systematized, so that observations of the more rapid and difficult pairs are obtained at the times most advantageous for determining their orbits.

A considerable number of micrometer observations of the comets of 1906 have been made by Messrs. AITKEN, MADDRILL, SMITH, and FATH.

A large number of photographs of *Jupiter's* sixth and seventh satellites have been obtained by Dr. PERRINE with the Crossley reflector for the purpose of improving our knowledge of their orbits. Photographs of *Saturn's* ninth satellite and *Neptune's* satellite have also been secured. Extensive experimental work with reference to future investigations with this instrument have also been conducted by Dr. PERRINE.

Very extensive observations of several well-known variable stars have been made with the one-prism spectrograph by Messrs. ALBRECHT and MADDRILL, as a basis for theses, in partial fulfillment of requirements for the degree of Doctor of Philosophy. In all cases these variables have been shown to be spectroscopic binaries, and their accurate observations will be of great value in the efforts that are constantly being made to determine why these and other stars of their class vary in brightness.

Mr. MADDRILL has given special attention also to the photometry of several variable stars with a view to determining possible relationships between peculiarities in their brightness- and velocity-curves. His photometric results are of very satisfactory accuracy.

A fruitful investigation has been made by Dr. ALBRECHT on the relation of the effective wave-lengths of blended spectral lines and stellar spectra of different types. He has shown that the effective wave-lengths of many blends change progressively with the spectral type.

A long list of minor investigations and results should for completeness be mentioned, but space is lacking.

The observatory has abundant cause for thanksgiving in that the great earthquake of April 18th did very little damage. Reference may be made to an article on this subject in an earlier number of these *Publications*. The D. O. Mills Observatory, Chile, had its corresponding experience only four months later, and was equally fortunate. Let us hope that

these trials, so closely connected in time and giving rise to so much anxiety, were but a horrible coincidence, and that they may not recur for many generations.

The installation of an important electric plant for lighting and power purposes began in May, under the difficult conditions of supply, labor, and finance induced by the earthquake and fire. It should be completed early in the year 1907. An automatic pumping plant, installed at the same time, is in operation, and promises to increase the water supply three- or fourfold, with little expense.

Acknowledgments are due to the Regents of the University of California, to Mr. D. O. MILLS, to Mr. W. H. CROCKER, and to the Carnegie Institution for generous financial support, and to all the members of the Observatory Staff for their enthusiastic and efficient aid in carrying out the scientific plans.

W. W. CAMPBELL, *Director*.

LOWELL OBSERVATORY, FLAGSTAFF, ARIZONA.

During the first part of the year the large telescope was employed in spectrographic work, the charting of star-fields with the Brashear photographic doublet and micrometric observations. Since July the doublet has been mounted on the 6-inch Clark refractor, and the time of the large telescope has been devoted, for the greater part, to spectrographic observations. During the summer and autumn further experiments in planetary photography were carried on.

Mr. SLIPHER'S programme of spectrographic work has consisted principally of line-of-sight observations of stars. Modification of parts of the large three-prism spectrograph were made by BRASHEAR in January, February, and March. The changes made, remounting of the prisms and providing the collimator with a curved slit, have proved very satisfactory, and have added much to the efficiency of the instrument. Observations were made with the three-prism spectrograph until the middle of August. During the autumn months spectrographic observations of the fainter stars were made with the single-prism spectrograph. The original mounting for the simple prism which made use of the spectrometer section of the large spectrograph, lacked stability for long exposures. But after modification of this part, from designs by Mr.

SLIPHER, no trace of flexure has been found for exposure of as much as four hours' duration on the one side of the meridian. In the single-prism instrument one of the dense flint prisms of the prism-train of the large spectrograph has been used. This prism gives a dispersion of 35 tenth-meters per millimeter at Hγ. By tipping the plate the camera is made to give a sharp focus over the range of spectrum comprised between K and λ 4600, over which region the measures are commonly extended. In the course of this work several stars have been found to have variable radial velocity, and the spectrum of ϵ *Capricorni* has been found to contain bright lines. Though the measurement of the plates is much in arrears, the results thus far obtained indicate a large field of work for this form of instrument. Of the spectra of variable stars photographed with the single-prism instrument the most interesting is perhaps that of *Mira Ceti,* secured at the recent unusually bright maximum of this star during December and January. One spectrogram was made with the three-prism instrument. With the improved sensitizing dyes now available, giving a fairly even deposit over the entire range of sensitiveness of the plate, it was possible to photograph the spectrum with the single-prism instrument from below B to Hδ. All the hydrogen lines covered by the plate are bright. (See note in the *Astrophysical Journal* for January, 1907, and the reproduction of one of the plates of the spectrum in the March number of that publication.) In connection with the spectrographic work, Mr. SLIPHER has experimented further with sensitizing dyes, particularly those active for the less refrangible end of the spectrum, for the application of such to photographic investigation of absorption bands in planetary spectra and also for work on the lower end of stellar spectra, with the result that plates more sensitive to the red can now be prepared. The greater rapidity and more perfect gradation of these plates than of those formerly available makes it possible to extend the study of the spectra of planets and stars considerably farther into the red.

A great many star-fields have been photographed with the Brashear doublet during the year. This lens was at first carried on the 24-inch refractor. When the mounting of the 6-inch Clark refractor was completed, in July, the doublet was mounted on it, and since then the time of this instrument has been devoted wholly to photography. This work was done

until June by Mr. J. C. DUNCAN, Lawrence Fellow at this observatory for 1905-1906. Since July the work has been continued by Mr. E. C. SLIPHER, fellow for the present year.

In addition to making photographs of star-fields and the series of photographs of Comet *c* 1905, Mr. DUNCAN made micrometric measures for position of Comets *c* 1905, *a* and *b* 1906.

In view of the approaching favorable opposition of *Mars*, further experiments in planetary photography have been carried on by Mr. LAMPLAND. It is hoped that the greater brightness and larger disk of the planet, together with such improvement as may be expected from past experience and more suitable and efficient apparatus, will bring still better results than were obtained in 1905. For the present, at least, the greatest value of the results obtained by photography is the evidence the negative brings to corroborate data obtained visually. The great mass of observational data and the results deduced therefrom, accumulated since SCHIAPARELLI'S epoch-making observations were begun, have been obscured and distorted more or less by unfounded skepticism, based on the idea that many of the observed phenomena are subjective effects or spurious products of observation. The questions raised have been thoroughly investigated from the standpoint of theory and experiment and found untenable. With the further confirmation of the visual results by photography, it seems that there should be no room for doubt in the matter.

PERCIVAL LOWELL.

NAVAL OBSERVATORY, MARE ISLAND, CALIFORNIA.

As indicated in the last annual report, this observatory was established mainly for keeping up the public time service for the Pacific Coast, and for the rating of chronometers used in the naval service. During the past year the work has been maintained as usual.

At the time of the great earthquake the time-signals were sent out the following day, but the Western Union Telegraph Company's lines were so deranged and congested with business that the signals could not always be delivered. Yet even during this trying period they managed to deliver the signals about every second day, which was sufficient for commercial purposes. The earthquake stopped two of the four clocks of

the observatory, and deranged the time of the other two by more than twenty seconds. The pendulums rubbed against the index ledges, and this with the shocks affected the rates of motion.

The earthquake was carefully observed here, and a full report has been submitted to the State Earthquake Commission. After this terrible disaster to the State, the theory of earthquakes ordinarily adopted seemed so improbable and so incapable of explaining the observed phenomena that a general survey of the subject was attempted, in the hope of gaining a better understanding of the cause of such disturbances. The results of this investigation have just been published in the *Proceedings* of the American Philosophical Society at Philadelphia. It is shown that the main cause of great earthquakes is the expulsion of lava from under the bed of the sea, by the explosive power of steam, which forms beneath the Earth's crust, owing to the secular leakage of the ocean bottoms. Another investigation is about finished which deals with the problem of the secular cooling of the Earth and the theory of contraction, so generally adopted in the physical sciences. The results obtained are not without interest to investigators.

A new Riefler clock, moving in an air-tight case, has just been installed in the observatory, and it promises to perform with great perfection, and will thus afford additional accuracy to the time service in the winter season, when long spells of cloudy weather are common.

T. J. J. SEE,
Professor of Mathematics, U. S. N.,
in charge of the Observatory.

SOLAR OBSERVATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON, MT. WILSON, CALIFORNIA.

The most important event of the year, so far as its bearing on the future of the observatory is concerned, was the gift of $45,000 by Mr. JOHN D. HOOKER, to meet the cost of a mirror of one hundred inches aperture for a great reflecting telescope. The difficulties in the way of constructing and using successfully a mirror of this size have been outlined elsewhere. It is sufficient to say here that the mirror is certain to give results of great importance in those classes of work where the finest definition is not essential, while there is good reason to hope

that for the direct photography of nebulæ, and for other investigations requiring even more perfect definition, there will be some nights in the year in which the full advantages of the large aperture will be realized. The glass disk has been ordered from the plate-glass works at St. Gobain, France, and work has been undertaken on the fireproof structure in which the grinding and polishing of the mirror will be done by Professor RITCHEY.

The work of research has included:

1. Daily photography of the Sun with the photoheliograph;
2. Daily photography of the Sun with the spectroheliograph;
3. Photography of the spectra of sun-spots;
4. Photography of the flocculi, for the determination of the radial velocity of the calcium vapor;
5. Spectrographic investigations of the solar rotation;
6. Bolographic investigations of the solar absorption;
7. Special studies of stellar spectra with a spectrograph of high dispersion;
8. Laboratory investigations;
9. Preliminary studies of the correlation of solar and magnetic phenomena.

The 5-foot spectroheliograph was erected in the Snow telescope-house in October, 1905. It has given admirable results from the outset, the daily records including photographs of the Sun with the calcium, hydrogen, and iron lines. These photographs have been studied in various ways, the principal routine investigation in which they are employed being a determination of the solar rotation. The daily motions of the calcium flocculi required for this purpose are measured by Miss WARE, with the "heliomicrometer," an instrument which permits the latitude and longitude of points on a photograph of the Sun to be measured directly, without computation. This instrument was constructed in the observatory shop and has been thoroughly tested during the year. Measures can be made with it as rapidly as with ordinary measuring-machines, and apparently with no less precision.

A comparative study of the hydrogen and calcium flocculi indicates that the former lie at a somewhat higher level in the solar atmosphere. Stereoscopic comparisons of calcium photo-

graphs taken at intervals ranging from one to ten hours have also proved very instructive.

Much time has been devoted to the study of the spectra of sun-spots, for the purpose of interpreting the cause of the strengthening and weakening of solar lines. The photographs of spot spectra used for this work were taken by Mr. ADAMS and Mr. ELLERMAN with the 18-foot Littrow spectrograph, used in conjunction with the Snow telescope. These photographs show thousands of lines not previously recorded, and have served admirably for present investigations. For the interpretation of the changes in the relative intensities of the lines, many laboratory experiments were made by Dr. GALE. It was soon found that by varying the temperature of a metallic vapor, such as iron or titanium, the changes in the relative intensities of the lines observed in sun-spots could be closely imitated. This work, carried out systematically, led to the conclusion that the characteristic line intensities of spot spectra are probably the result of the reduced temperature of the spot vapors, as compared with those of the ordinary reversing layer. This conclusion was confirmed by the discovery in spot spectra of the flutings of titanium, which do not appear to be present at the higher temperature of regions outside of spots.

A study of the spectrum of *Arcturus*, photographed with a spectrograph of very high dispersion, showed that the lines that are strengthened in sun-spots are in general strengthened in this star, at least in the region investigated. Lines that are weakened in sun-spots also appear to be weakened in *Arcturus*. This is a natural result if we assume a spot to be a comparatively cool region on the Sun, and if we suppose *Arcturus* to be a star like the Sun, cooled to a temperature of the same order as that of sun-spots. The presence of titanium flutings in third-type stars affords another close bond of connection between these stars and sun-spots. Results of this character, when followed up with the aid of the 60-inch reflector, should throw much light on the temperature classification of stars.

The radial motion of the calcium vapor in the flocculi has been studied spectrographically by Mr. ADAMS. The average displacement of the H_3 and K_3 lines corresponds to a velocity of approach of the calcium vapor amounting to about 0.41^{km} per second. The varying displacements obtained at different times, however, indicate that general conclusions should be

based only on very extensive investigations. The results given by the bright lines H_2 and K_2 also show a displacement toward the violet, so that the calcium vapor in the flocculi may be regarded as moving upward.

Mr. ADAMS is engaged on an extensive study of the solar rotation, based upon comparative photographs of the spectra of opposite limbs, made with the 18-foot spectrograph of the Snow telescope. The results, so far as reduced, are very consistent, and should prove to be an important contribution to this subject.

Bolographic studies of the absorption of the solar atmosphere, made by Dr. PALMER, with the advice and co-operation of Mr. ABBOT, seem to indicate that the absorption may fluctuate in an irregular manner within short periods. No satisfactory conclusions can be drawn, however, until the investigation has been carried farther and correlated with simultaneous studies of the solar constant.

Professor E. F. NICHOLS, of Columbia University, carried on two special investigations during the summer. One of these was the study of the effect of the ionization produced by X-rays upon the absorption or radiation of a gas or vapor. The second investigation dealt with the question whether the "Reststrahlen" obtained after repeated reflections from rock-salt surfaces reach us in any appreciable amount from the Sun.

The latitude and longitude of the Solar Observatory were determined by Messrs. SMITH and McGRATH, of the U. S. Coast Survey. The results obtained are as follows:—

	Mt. Wilson Triangulation Station.	Snow Telescope Pier.
Latitude	34° 12′ 59″.72	34° 12′ 59″.53
Longitude	118 3 45 .54	118 3 34 .89

The Smithsonian Institution sent a second expedition to Mt. Wilson during the summer of 1906, for the purpose of continuing the work undertaken in 1905. Although the season was hardly as satisfactory as the previous one, a large number of determinations of the solar constant were obtained. These are of a high order of precision, and should leave no doubt, when reduced, of the character of the variations which the results of 1905 seemed to exhibit. The admirable methods developed by Mr. ABBOT, in conjunction with the late Secretary LANGLEY,

seem well calculated to clear up the long-standing question as to the variability of the solar radiation.

The work of the Computing Division has been organized and placed under the direction of Mr. ADAMS. A series of offices added to our building in Pasadena provide suitable quarters for this work. Three computers, Miss WARE, Miss LASBY, and Miss SMITH, are at present employed. Miss WARE, as already stated, is engaged in the measurement of solar photographs with the "heliomicrometer." Miss LASBY is measuring Mr. ADAMS's photographs of spectra taken for the determination of the solar rotation. Miss SMITH is measuring the area of the calcium flocculi, in regions ten degrees square on the solar surface, for the purpose of ascertaining the distribution and variation of the solar activity. Special apparatus, devised for this purpose, was constructed in the observatory instrument-shop.

The work of the Construction Division has made admirable progress under the direction of Professor RITCHEY. Work has advanced on the 60-inch mirror and its mounting, the heavy parts of which were received from the Union Iron Works in the autumn. In addition, many smaller instruments have been constructed. The five-ton automobile truck, to be used for transporting the mounting of the large reflector and the steel for the building and dome in which it is to stand to the summit of the mountain, has also arrived in Pasadena. The work of widening the "New Trail" into a road is well advanced and will be completed in the spring. This work has been carried out under the immediate superintendence of Mr. GODFREY SYKES, of the Desert Botanical Laboratory of the Carnegie Institution, acting under the general direction and with the active co-operation of Professor RITCHEY.

Further details of the work of the year may be found in the Annual Report of the Director, in Year Book No. 5 of the Carnegie Institution, and in *Contributions from the Solar Observatory*, Nos. 3 to 14.

GEORGE E. HALE, *Director.*

STUDENTS' OBSERVATORY, BERKELEY ASTRONOMICAL DEPARTMENT, UNIVERSITY OF CALIFORNIA.

The year ending December last has been notable for a marked increase in enrollment in the courses offered by the Berkeley Astronomical Department. The number of students

during the fall term of the year 1906 was 216, the same as the combined enrollment for the two preceding terms. With the enrollment during the current term, the attendance for the academic year (1906-1907) has reached 378, as against 216 for the preceding year.

The staff of the department has devoted practically all of its time to instruction and has had to forego the much-desired completion of several astronomical investigations. The department was further seriously handicapped during the fall term by a prolonged illness of Mr. EINARSON, the assistant.

Nevertheless, the regular computation by the "Short Method" of one or more preliminary orbits of all newly discovered comets was continued during the year, with the exception of one case, by Dr. CRAWFORD, generally with the assistance of graduate students.

In his capacity as member and secretary of the State Earthquake Investigation Commission, the Director has devoted much time to the collection and systematizing of data on the California earthquake of April 18th.

On July 1, 1906, Dr. CRAWFORD was promoted to be Assistant Professor of Practical Astronomy.

Important additions to the instrumental equipment have not been made. The observatory has been fortunate, however, in having the use of an Omori tronometer belonging to the Imperial Earthquake Investigation Commission of Japan. With the aid of this instrument numerous good records of after-shocks have been secured, as well as records of three earthquakes at a distance, including the Valparaiso earthquake in August.

The work on the Watson asteroids has progressed sufficiently to make it certain that the tables of twelve asteroids reported on a year ago will go to press in April.

The chief assistant in this work has been Miss ESTELLE GLANCY, Dr. NEWKIRK having accepted a position as Carnegie Research Assistant at the Lick Observatory in September.

Dr. CRAWFORD'S further investigation of the constant of refraction, and Dr. NEWKIRK'S tables for the reduction of measured photographic positions and his investigation of the Repsold measuring-engine are to be published in April.

A. O. LEUSCHNER, *Director.*

GENERAL NOTES.

The Work of the Harvard College Observatory.—From Professor E. C. PICKERING's report for the year ending September 30, 1906, it appears that the work of the Harvard College Observatory continues to be mainly the quantitative and qualitative analyses by visual and photographic methods of the light of the stars. By means of photometers attached to the east equatorial at Cambridge, and of the meridian photometers at Cambridge and at Arequipa, many thousands of measures have been made during the year of the brightness of stars, with the object (*a*) of extending to stars of the thirteenth magnitude the plan of furnishing standards of magnitude on a uniform scale well distributed over the entire sky, and (*b*) of increasing our knowledge of the variable stars, especially of those of long period and of those of the *Algol* type. Miscellaneous photometric measures include the photometric measures of twenty-nine eclipses of *Jupiter's* satellites.

A large number of photographs, including spectrum plates, have been taken with the 11-inch and 8-inch Draper telescopes at Cambridge, and with the 8-inch Bache, the 13-inch Boyden, and the 24-inch Bruce telescope at Arequipa. The study of these plates has already revealed many new variable stars, stars with bright hydrogen lines, etc. Other plates have been utilized to extend the classification of stellar spectra to fainter stars on the plan of the classification given in volume XXVIII of the *Annals*. The great majority of the plates are necessarily stored for future study.

Professor PICKERING again calls attention to the urgent need of the observatory of suitable fireproof buildings for housing the admirable library of the observatory, one of the finest astronomical libraries in the world, for the photographic laboratory, and for a workshop. A still greater desideratum is an addition to the staff of assistants. As Professor PICKERING says, "Perhaps the greatest return could be obtained by the employment of more assistants for the study of the unique collection of astronomical photographs. This collection now contains 189,200 photographs of the stars, and is like a library of that size with only about twenty readers."

An Interesting Variable.—The leading article in the *Astronomische Nachrichten*, No. 4148, by G. MÜLLER and P. KEMPF, gives the determination of the period and the light-curve of a new short-period variable of the *δ Cephei* type. The star is located in the constellation *Cassiopeia*, B. D. 68° 200, and has an average brightness of a little less than the sixth magnitude. Its period was found to be 1.9498 days. But the chief interest lies in the smallness of the range of brightness; this was found to be only 0.33 of a magnitude. Observations were made photometrically by both of the authors, and in order to be certain that the variations found were in reality not large accidental errors of observation they requested a third observer, Mr. K. GRAFF, of Hamburg, to make visual observations upon the star by ARGELANDER'S method, without, however, giving him any exact knowledge of the period to be expected. The observations of Mr. GRAFF completely confirmed those obtained at Potsdam, and there seems to be no doubt about the reality of the variation. When it becomes possible to differentiate with certainty a variation of a quarter of a magnitude from the accidental errors of observation, it serves to illustrate the degree of precision attainable in modern photometric work.

An Unknown Comet.—During 1905 Professor E. E. BARNARD, of the Yerkes Observatory, was stationed for a time at the Solar Observatory of the Carnegie Institution on Mt. Wilson, in California, engaged in photographing the southern portions of the Milky Way with the Bruce photographic telescope of the Yerkes Observatory. After returning from the expedition a re-examination of the plates disclosed the trail of a very faint comet on each of three plates taken on July 22, 1905. These plates have been measured by Professor BARNARD, giving an accurate position of the object, and the results have been published in the *Astronomische Nachrichten*, No. 4153. The comet had a right ascension of between eighteen and nineteen hours and a declination between 20° and 21° south. So far as known, it was neither seen visually by any one nor photographed at any other place. The chief interest in the object lies in the possibility of its belonging to the class of periodic comets. If such should be the case, and it should be observed at some future return to the neighborhood of the

Earth, the position determined by Mr. BARNARD might prove very valuable in fixing its orbit.

Heights of Meteors.—Under the title, "Heights of Large Meteors Observed in 1906," (*Astronomische Nachrichten,* No. 4152,) W. F. DENNING gives some interesting results obtained from the observations of ten meteors in England by himself and persons co-operating with him. The height at appearance varies between fifty-nine and eighty-nine miles, with an average value of seventy miles; the height at disappearance varies between twenty-two and fifty-six miles, with an average value of forty miles; the length of path varies between twenty-four and seventy-two miles, with an average of forty-four miles; the velocity in miles per second (given for only six) varies between fifteen and thirty, with an average value of twenty-two. It would be interesting if some one could devise a means of computing, or even roughly estimating, the mass which must be possessed by a meteor in order that it may give forth light during its flight through a certain stretch of the upper atmosphere at a given velocity.

Isaac Roberts's Celestial Photographs.—Mrs. DOROTHEA ISAAC-ROBERTS has published in the *Astronomische Nachrichten,* No. 4154, a "Preliminary Catalogue of ISAAC ROBERTS's Collection of Photographs of Celestial Objects." This collection consists of 2,485 original negatives of stars, star-clusters, nebulæ, and other celestial objects, together with many positives on glass and on paper. Over half of the negatives were taken with a 20-inch reflector of ninety-eight inches focal length, and the balance were taken with various lenses up to five inches in diameter.

Mrs. ROBERTS proposes to make this fine collection of negatives available for the advancement of astronomical science, as may be seen from the following quotation from her article:—

"As soon as circumstances permit, a complete list of ISAAC ROBERTS's tribute to astronomy will be published, in accordance with the wishes and instructions of the deceased.

"The number of copies of the forthcoming paper being very limited, the observatories and astronomers, official or amateur, who are specially interested in photographic astronomy will please send in their names to the address given below, early in 1907, in order that

the various parts of the complete catalogue may be sent to them in course of time.

"Positives-on-glass reproduced from the Isaac Roberts negatives will be lent for the purpose of micrometric measurements, if application be made, and provided that the documents be returned after completion of the measurements."

Mrs. ROBERTS's address is Château Rosa Bonheur, By-Thomery, Seine et Marne, France.

New Asteroids.—The number of asteroids now exceeds six hundred. Dr. J. BAUSCHINGER, Director des Astronomisches Rechen-Institut, Berlin, has recently printed, in the *Astronomische Nachrichten,* No. 4156, sets of elements for twenty-five of these small bodies discovered during 1905 and 1906.

The *Monthly Notices* of the Royal Astronomical Society for December, 1906, contains an article by Professor H. H. TURNER, "On the Possibility of Improving the Places of Reference-Stars for the Astrographic Catalogue from the Photographic Measures," which is characterized by the simplicity of method and evident practical value which mark his other contributions on the subject of photographic measures. In the process of the reduction of the measured rectangular co-ordinates of star-images on a photographic plate to the right ascension and declination of the corresponding stars, plate constants are derived with the help of the images of stars whose positions are known from meridian or other independent observations. The unavoidable errors in the positions of these stars of reference affect the plate constants and through them the positions of the previously unknown stars which result from the measures. It is the readjustment of the assumed co-ordinates of the stars of reference by a comparison of the measures of their images made on overlapping plates that is treated in this paper.

In the Oxford reductions for the astrographic catalogue it has been customary to substitute for the least-square solution of the equations for the plate constants a method in which all the equations are combined to form eight derived ones, four of which involve the constants *a, b, c,* and the remaining four the constants *d, e, f.* The four derived equations of each group are obtained by adding the equations arising from the

star-images in the four quadrants of the plate respectively. Each of the four derived equations of one group may be regarded as arising from a single fictitious star, its weight being equal to the number of stars in its quadrant. Mr. TURNER shows that if the four equations are of equal weight, and if the four fictitious stars are in the center of their respective quadrants, the four residuals after solution, either by his method or by the method of least squares, are $+ I$, $- I$, $+ I$, $- I$, respectively, where I is the algebraic sum of the absolute terms of the four equations, two of them taken with the opposite sign. This quantity I is called the "inconsistency" for the plate. It will be zero in the assumed case if the co-ordinates of the comparison-stars are correct, and the measures are affected by no errors that are not linear functions of the measured co-ordinates. Where the actual state of affairs is not too unsymmetrical it is possible therefore to write down the residuals before the solution is made and to determine, without a solution of the equations, how the residuals would be affected by arbitrary changes in the co-ordinates of the comparison-stars,—that is, in the absolute terms of the equations of condition. It would be entirely possible to make the inconsistency for a single plate zero without improving the plate constants, but any changes that materially reduce the inconsistencies of a series of overlapping plates would undoubtedly improve the plate constants of all of them.

Professor TURNER has not arrived at any general and entirely satisfactory method of accomplishing this adjustment, but the tabulation of the inconsistencies of a series of overlapping plates in "diagrammatic" form will undoubtedly lead to such adjustments, provided the symmetry of arrangement of the comparison-stars is sufficient to render applicable his theorem regarding the residuals.

The Gold Medal of the Royal Astronomical Society Awarded to Professor E. W. Brown.—The gold medal of the Royal Astronomical Society has this year been awarded to Professor ERNEST WILLIAM BROWN for his "Researches in the Lunar Theory."

On presenting the medal to Professor BROWN at the annual meeting of the society, February 8, 1907, the president, Mr. WILLIAM H. MAW, reviewed the work of the distinguished

medalist in an able and comprehensive address, from which the following is taken.

Professor BROWN is the seventh astronomer to whom the gold medal of the Royal Astronomical Society has been awarded for work in connection with the lunar theory.

In a paper entitled "Theory of the Motion of the Moon, Containing a New Calculation of the Expressions for the Co-ordinates for the Moon in Terms of the Time," published in volume LIII of the *Memoirs,* he has clearly stated the nature of the problem on which he has been engaged, in the following words:—

"The formation of numerical expressions deduced as a consequence of the Newtonian laws of motion and gravitation which shall represent the position of the Moon at any time may be roughly divided into three stages. As a first step, we consider each of the three bodies—the Sun, the Earth, and the Moon—as a sphere of mass equal to its actual mass, and arranged in concentric layers of equal density. The Earth (or center of mass of the Earth and Moon) is supposed to move round the Sun in a certain ideal elliptic orbit, and all disturbances of this orbit and of the Moon from any other source than the ideal Sun and Earth are neglected. The first stage constitutes nearly the whole of the problem of three bodies as far as the particular configuration of the Sun-Earth-Moon system is concerned. When this is done, we proceed to the second step, which involves the determination of the effects due to the difference between the actual and the ideal motions of the Earth and Sun, to the influence exercised by the other bodies of the solar system, and to the differences between the real and ideal arrangements of the masses of the bodies. The calculations so far may, theoretically at least, be made without any knowledge of the configuration of the system at any given time or times, beyond a general idea of the order of magnitude of certain of the constants involved. The third and final stage consists in a determination by observation of the various constants which have entered into the theory and the substitution of their values, so as to obtain numerical expressions for the co-ordinates in terms of the time."

It is the completion of the first of these stages which has primarily been the object of Professor BROWN's past labors; and as a result he has, after arduous work extending over the past fifteen years, completed the solution of the problem of three bodies for the case of Sun-Earth-Moon with an accuracy very far in excess of that attained by any of his predecessors in this line of research.

Dr. G. W. HILL, who speaks with the highest authority, has expressed the following opinion on Professor BROWN's work:—

"Much as we rightly welcome the results of Professor BROWN's devoted labors, we should be unwarranted in assuming that their employment in the lunar tables would give rise to a marked improvement in the representation of observations. A slight one indeed might be expected; but it has been evident for some time that the Moon deviated from its calculated orbit more because it is subject to irregular forces, which we have not yet the means of estimating, than because the tables are affected by slight defects in the mathematical treatment of the forces which are already recognized. This circumstance in no sense diminishes the credit due to Professor BROWN's work."

By giving accurate values to the known perturbations, Professor BROWN has defined more clearly the further irregularities of which the explanation has yet to be ascertained.

The precautions taken by the medalist to secure accuracy in the final results have been most refined. In accordance with the original programme, every coefficient in longitude, latitude, and parallax which is so great as one hundredth of a second of arc, has been computed, and is regarded as accurate to at least this amount, the results being obtained to one thousandth of a second. To avoid the occurrence of errors of computation, equations of verification have been computed at every step of the work, every page of the manuscript having, on the average, not less than two test equations computed. The medalist is the first lunar theorist to use independent equations of verification, thus creating a higher degree of confidence in his results than could ever come from mere duplicate calculation.

In devising the details of his research, the medalist arranged the work so that considerable proportions could be done by computers; but as a matter of fact only one—Mr. IRA L. STERNER, of Haverford College, of whose ability and accuracy Professor BROWN speaks in the highest terms—has been employed. "The calculations have probably occupied altogether eight or nine thousand hours. There were about 13,000 multiplications of series made, containing some 400,000 separate products; the whole of the work required the writing of between some four or five millions of digits and *plus* and *minus* signs."

Professor BROWN has completed his solution of the problem of three bodies for the case of the Sun-Earth-Moon by methods involving striking elegance and originality, and showing great powers of resource. He has, however, by no means

finished his labors. As he himself has pointed out, in announcing the completion of the main problem, much still remained to be done before it was advisable to proceed to the construction of tables. On this work he is now engaged, and we may rest assured that he will continue to bring to bear upon it that energy and power of organized inquiry which have enabled him already to secure such brilliant results.

Professor BROWN is an Englishman who has long been resident in America, and who has for the past sixteen years been connected with Haverford College. That association will, however, be broken in the ensuing summer, and next autumn Professor BROWN proceeds to Yale University. It is exceedingly gratifying to know that his work on the lunar theory, which he has been able to carry on at Haverford under most favorable conditions, will not be interrupted by this change. The Yale authorities have recognized the importance of his work by arranging special facilities for its continuance, and have also most generously undertaken to provide the funds required for both the preparation and publication of the lunar tables which will form the natural outcome of Professor BROWN's labors. A. O. L.

Volume I, number I, of the *Journal of the Royal Astronomical Society of Canada* bears the date January-February, 1907. The object of the society is, in the words of the editor, "to extend and popularize the study of astronomy, astrophysics, and related branches of science." The pages of the journal are to be open to accounts of the work of amateurs as well as to technical papers. For the present the publication is to appear bi-monthly. The editors hope, however, soon to be able to issue it monthly.

Among the papers of especial interest in this first number may be mentioned the president's address, on "Progress in Astronomy and Astrophysics during 1906," and an article by J. S. PLASKETT, on "The Spectrum of *Mira Ceti*." The "Notes from the Dominion Observatory," "Brief Astronomical Reviews," and "Astronomical News" are also worthy of mention as interesting and valuable features.

Notes from "Science."—A bill has been introduced in the legislature incorporating the New York Observatory and Nau-

tical Museum, to which reference has already been made in *Science*. It is stated in the charter that this museum is "for the purpose of encouraging and developing the maritime interests of New York City, of advancing the general knowledge of the safe navigation of the sea, of the development of harbor facilities, of prosecuting original researches in astronomy and navigation and in kindred subjects, and of affording instruction in the same."

Substantially, the museum would be placed on the same basis as the Museum of Natural History and the Metropolitan Museum of Art. The city is to provide the land and is to erect the buildings, while the corporation is to secure by private subscription not less than $300,000 for equipping the nautical museum and observatory and for prosecuting the other objects of the institution.

The French Government has made Professor SIMON NEWCOMB, U. S. N., (retired), Commander of the Legion of Honor.

Mr. E. B. McCLELLAN, third assistant at the Radcliffe Observatory, Oxford, died on January 2d, at the age of forty-five years.

Mr. H. F. NEWALL, of Trinity College, Cambridge, assistant director of the observatory, has been elected president of the Royal Astronomical Society, in succession to Mr. W. H. MAW.

Planet Markings.—At the 628th meeting of the Philosophical Society of Washington, held on February 2d, Professor NEWCOMB read a paper on "The Optical and Psychological Principles Involved in the Interpretation of the Markings on the Disks of the Planets." A short outline of the paper may be found in *Science* for March 1, 1907.

Mr. JAMES D. MADDRILL, of the University of California, Fellow in the Lick Observatory, who will take the examinations for the degree of Doctor of Philosophy in Astronomy, Physics, and Mathematics in May, has been appointed by the Superintendent of the United States Coast and Geodetic Survey to succeed Dr. SIDNEY D. TOWNLEY as observer at the International Latitude Observatory in Ukiah, and will enter upon his duties in July. A. O. L.

Obituary.—The *Astronomische Nachrichten,* No. 4145, contains a notice concerning the life and works of JEAN ABRAHAM CHRÉTIEN OUDEMANS, who died on December 14, 1906, at the age of seventy-nine years. OUDEMANS was for many years Professor of Astronomy and Director of the Observatory at the University of Utrecht. He was chiefly interested in the practical side of astronomy, and as an observer and computer held high rank among his contemporaries. He was also interested in geodetic work, and spent eighteen years in charge of the triangulation of the Dutch East Indies. The result of this work was published in six volumes under the title of "Triangulation of Java." Although Professor OUDEMANS retired from the directorship of the Utrecht Observatory in 1898, yet he did not give up his astronomical work, and only a short time before his death presented a paper at a meeting of the Royal Academy of Sciences of Amsterdam, on the "Mutual Occultations and Eclipses of the Satellites of *Jupiter* in 1908," an abstract of which will be found in these notes in our next number.

Miss AGNES MARY CLERKE, the scientific writer, died on Sunday morning, January 20th, at her residence, 68 Redcliffe Square, S. W., London, England, at the age of sixty-four. An astronomical correspondent writes with reference to Miss CLERKE:—

"During the last century two ladies only were elected honorary members of the Royal Astronomical Society—CAROLINE HERSCHEL and Mrs. SOMERVILLE. The new century soon saw fresh honorary members elected, and among them Miss AGNES CLERKE, whose last important work, 'Problems in Astrophysics,' was of such great scientific value that the Astronomical Society could no longer ignore her claims to public recognition by them. And when we say 'last important work' we must acknowledge also the outstanding merit of two earlier books, 'The System of the Stars' and 'History of Astronomy in the Nineteenth Century,' besides less important volumes, 'The HERSCHELS and Modern Astronomy,' 'Modern Cosmogonies,' and many scientific magazine articles, principally of the nature of reviews or interpretations of results, in which her keen insight into the true significance of observed physical facts was as wonderful as her fluency and command of language, so that both from the literary and scientific standpoints she must be ranked as a great scientific writer. No one writing a history of modern astronomy can fail to acknowledge the great debt owed to the masterly array of facts in her 'History.' No worker in the vast field of modern sidereal astronomy opened by the genius of HERSCHEL and greatly widened by the application of the spectroscope

to the chemical and physical problems of the universe lacked due recognition by Miss CLERKE, who performed as it seemed no other writer could have done the work of collation and interpretation of this enormous mass of new material, ever pointing the way to new fields of investigation, often by one pregnant suggestion sweeping aside a whole sheaf of tentative conjectures and indicating, if not the true line—for in many cases the truth is yet to seek—at least, a plausible and scientific line well worth pursuing. She will be missed at the meetings of the Royal Astronomical Society, at which she was a constant visitor even before her election as an honorary member, and where her clear judgment was at times called upon to determine the value of some new suggestion in the domain of celestial physics. She was not a practical astronomer in the ordinary sense; but her death, on Sunday morning, leaves a gap that will be hard to fill. She was the daughter of Mr. JOHN WILLIAM CLERKE, who died in London in 1890. Her sister, Miss C. M. CLERKE, who died a few months ago, also wrote on astronomical subjects, though in a far more humble way."—*The Times, London.*

NEW PUBLICATIONS.

BELOPOLSKY, A. Untersuchung der Ca-Linien am Sonnenrande. Mitteilungen der Nikolai-Haupt Sternwarte zu Pulkowo. Band I, No. 12. 1907. 4to. 23 pp.

BONSDORFF, I. Beobachtungen von δ *Cassiopejæ* mit dem grossen Zenitteleskop. Mitteilungen der Nikolai-Haupt Sternwarte zu Pulkowo. Band II, No. 13. 1907. 4to. 16 pp.

CANNON, ANNIE J. Second catalogue of variable stars. Cambridge: Annals of the Astronomical Observatory of Harvard College. Vol. LV, Part I. 1907. 4to. iii + 94 pp. Paper.

COOKSON, BRYAN. Determination of the mass of *Jupiter* and orbits of the satellites from observations made with the Cape heliometer. Edinburgh: Annals of the Royal Observatory, Cape of Good Hope. Vol. XII, Part II. 1906. 4to. 215 pp. Paper. 6s.

DE SITTER, W. A determination of the inclinations and nodes of the orbits of *Jupiter's* satellites, from photographic plates taken at the Royal Observatory, Cape of Good Hope. Edinburgh: Annals of the Royal Observatory, Cape of Good Hope. Vol. XII, Part III. 1906. 4to. 139 pp. Paper. 4s.

FRANZ, J. Der Mond. Leipzig: Teubner. 1906. 12mo. 132 pp.

HALM, JACOB. New reduction of Henderson's catalogue for the epoch 1840.0. Glasgow: Annals of the Royal Observatory, Edinburgh. Vol. II. 1906. 4to. xl + 104 pp. Cloth. 6s.

LOUD, F. H. Notes on the computation of logarithms. Colorado Springs: Semi-annual Bulletin of the Colorado College Observatory. 1907. 8vo. 19 pp.

LUNT, JOSEPH. The spectra of silicon, fluorine, and oxygen. Edinburgh: Annals of the Royal Observatory, Cape of Good Hope. Vol. X, Part II—Spectroscopic Researches. 1906. 4to. 43 pp. Paper. 3s.

MÜLLER, G., und KEMPF, P. Photometrische Durchmusterung des Nördlichen Himmels, enthaltend die Gröszen und Farben aller Sterne der B. D. bis zur Grösze 7.5. Generalkatolog. Potsdam: Publikationen des Astrophysikalischen Observatoriums zu Potsdam. Band XVII. 1907. 4to. xxxv + 293 pp. Boards. 18m.

OUDEMANS, J. A. C. Mutual occultations and eclipses of the satellites of *Jupiter* in 1908. Parts I and II. Reprinted from the Proceedings of the Amsterdam Academy of Sciences, 1906. 32 and 15 pp.

WEINEK, L. Astronomische Beobachtungen an der K. K. Sternwarte zu Prag. in den Jahren 1900-1904. Prag. 1907. 4to. vi + 106 pp. Plates.

WOOD, R. W. Physical optics. New York: Macmillan Co. 1907. 8vo. 546 pp. Cloth, $3.50.

Positions of *Phœbe,* 1898-1904. Cambridge: Annals of the Astronomical Observatory of Harvard College. Vol. LX, No. III. 4to. 40 pp. Paper.

Eclipses of *Jupiter's* satellites, 1878-1903. Cambridge: Annals of the Astronomical Observatory of Harvard College. Vol. LII, Part I. 4to. iii + 148 pp. Paper.

The Nautical Almanac for 1910. Edinburgh: 1906. 8vo. xiii + 602 + 44 pp. Paper, 2s 6d.

Catalogue of stars for the equinox 1900.0, from observations made at the Royal Observatory, Cape of Good Hope, during the years 1900-1904. Edinburgh: 1906. 4to. xiii + 123 pp. Cloth, 4s 6d.

A catalogue of 8,560 astrographic standard stars between declinations —40° and —52° for the equinox 1900.0, from observations made at the Royal Observatory, Cape o Good Hope, during the years 1896-1899 (with three appendices). Edinburgh. 1906. 4to. lix + 403 pp. Cloth.

Results of meridian observations of stars made at the Roy Observatory, Cape of Good Hope, in the years 1900 1904. Edinburgh. 1906. 4to. xxx + 274 pp. Cloth.

Astronomical and magnetical and meteorlogical observatio made at the Royal Observatory, Greenwich, in the yea 1904. Edinburgh. 1906. 4to. cxlvi + (334) + (96) + 155 + 97 + *lviii* + (cxliii) + 9 + 23 + vii + 24 pp. Cloth

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS HELD ON MARCH 30, 1907, AT 7:30 P.M.

President LEUSCHNER presided. A quorum was present.

The following resolution was adopted:—

Resolved, That the Publication Committee be authorized to expend $600 for *Publications* to the end of the current calendar year.

Adjourned.

MINUTES OF THE NINETEENTH ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE LAW OFFICES OF CUSHING, GRANT & CUSHING, 1652 O'FARRELL STREET, MARCH 30, 1907, AT 8 P.M.

The meeting was called to order by President LEUSCHNER. A quorum was present. The minutes of the last meeting were approved.

The Committee on Nominations reported a list of names proposed for election as Directors and Committee on Publication. Messrs. BAIRD and CORNISH were appointed as tellers. The polls were open from 8:15 to 9 P.M., and the following persons were duly elected to serve for the ensuing year:—

For Directors: R. G. AITKEN, A. H. BABCOCK, CHAS. BURCKHALTER, WM. H. CROCKER, W. W. CAMPBELL, CHAS. S. CUSHING, GEORGE E. HALE, S. D. TOWNLEY, F. R. ZIEL, R. T. CRAWFORD, D. S. RICHARDSON.

For Committee on Publication: R. G. AITKEN, S. D. TOWNLEY, B. L. NEWKIRK.

REPORT OF THE DONOHOE COMET-MEDAL COMMITTEE FOR THE YEAR 1906.

The following comets were discovered during the year 1906:—

Comet *a* 1906, an unexpected comet, was discovered by Professor W. R. BROOKS at Geneva, New York, on January 26th.

Comet *b* 1906, an unexpected comet, was discovered by Dr. A. KOPFF at Heidelberg, Germany, on March 3d.

Comet *c* 1906, an unexpected comet, was discovered by D. ROSS at Melbourne, Australia, on March 17th.

Comet *d* 1906, FINLAY's periodic comet, was re-discovered by Dr. A. KOPFF at Heidelberg, Germany, on July 16th.

Comet *e* 1906, an unexpected comet, was discovered by Dr. A. KOPFF at Heidelberg, Germany, on August 22d.

Comet *f* 1906, HOLMES's periodic comet, was re-discovered by Professor MAX WOLF at Heidelberg, Germany, on August 28th.

Comet *g* 1906, an unexpected comet, was discovered by Professor H. THIELE at Copenhagen, Denmark, on November 10th.

Comet *h* 1906, an unexpected comet, was discovered by Rev. J. H. METCALF at Taunton, Massachusetts, on November 14th.

The Donohoe Comet-Medal of the Astronomical Society of the Pacific has been awarded to the discoverers of Comets *a*, *b*, *c*, *e*, *g*, and *h*.

It should be noted that Comets *b*, *d*, *e*, *f*, and *h* 1906 were discovered by photographic methods.

Respectfully submitted,

W. W. CAMPBELL,
CHAS. BURCKHALTER, } *Committee.*
C. D. PERRINE,

The Treasurer submitted his Annual Report, as follows:—

Annual Statement of the Receipts and Expenditures of the Astronomical Society of the Pacific for the Fiscal Year Ending March 30, 1907.

GENERAL FUND.

Receipts.

1906. April 1st. Balance				$ 36 11
Received from—				
Dues for 1906 and previous years		$191 05		
Dues for 1907		555 40		
			$ 746 45	
Life membership fee			50 00	
Sales of *Publications*			39 00	
Legacy, Estate of Morris Reiman		500 00		
Less inheritance tax	$18 90			
Less lawyer's fees	50 00			
		68 90	431 10	
Life Membership Fund (interest)			72 04	
Life Membership Fund (loan)			276 25	
John Dolbeer Fund (interest)			219 47	
Wm. Alvord Fund (interest)			180 84	
London & Lancashire Fire Insurance Company, for loss under Policy No. 4823220, on claim of $2,000			1,900 00	
				$3,915 15
				$3,951 26
Less transfer to Life Membership Fund (fee)			$ 50 00	
Less transfer to Montgomery Library Fund (fire insurance loss)			1,900 00	
				1,950 00
				$2,001 26

Expenditures.

For *Publications*—Printing Nos. 106 to 112	$1,115 75		
Illustrations	9 10		
		$1,124 85	
Reprints	$36 50		
Stationery and printing	71 20		
Postages	60 00		
Rent	.. ..		
Salary Secretary-Treasurer	180 00		
Expressages	18 71		
Janitor	11 90		
Gas	20		
Insurance premiums	17 60		
Fee re claim vs. Rhine-Moselle Fire Insurance Co.	5 00		
Lantern at lecture	8 00		
Engrossing	2 25		
Notary fees	3 50		
Rent safe deposit box	5 00		
Bank exchanges	30		
		420 16	
			1,545 01
1907. March 30th. Balance			$ 456 25

Dues outstanding—

For 1906	$100 00
For 1907	310 00
	$410 00

LIFE MEMBERSHIP FUND.

1906.	April 1st. Balance		$1,953 95
	Received from General Fund (fee)		50 00
	Interest		72 04
			$2,075 99
	Less transfer to General Fund (interest)	$ 72 04	
	Less transfer to General Fund (loan)	276 25	
			348 29
1907.	March 30th. Balance		$1,727 70

ALEXANDER MONTGOMERY LIBRARY FUND.

1906.	April 1st. Balance	$1,533 87
	Received from London & Lancashire Fire Insurance Company, on claim of $2,000	1,900 00
	Interest	67 50
1907.	March 30th. Balance	$3,501 37

DONOHOE COMET-MEDAL FUND.

1906.	April 1st. Balance	$ 766 57
	Interest	28 94
		$ 795 51
	Less engraving medals Nos. 53, 54, 55, and postage	2 85
1907.	March 30th. Balance	$ 792 66

BRUCE MEDAL FUND.

1906.	April 1st. Balance	$2,669 04
	Interest	122 61
1907.	March 30th. Balance	$2,791 65

JOHN DOLBEER FUND.

1906.	April 1st. Balance	$5,000 00
	Interest	219 47
		$5,219 47
	Less interest expended for *Publications* (see General Fund)	219 47
1907.	March 30th. Balance	$5,000 00

WILLIAM ALVORD FUND.

1906.	April 1st. Balance	$5,000 00
	Interest	180 84
		$5,180 84
	Less interest expended for *Publications* (see General Fund)	180 84
1907.	March 30th. Balance	$5,000 00

FUNDS.

Balances as follows:—

General Fund.		
With Donohoe-Kelly Banking Company................		$ 456 25
Life Membership Fund.		
With German Savings & Loan Society................	$ 727 70	
South Pacific Coast Railway Co. 1st Mortgage 4 per cent guaranteed (by S. P. Co.) $1,000, Gold Bond No. 3406	1,000 00	
(Interest Jan. and July; principal due July 1, 1937.)		1,727 70
Alexander Montgomery Library Fund.		
With Security Savings Bank..........................	$1,377 35	
Oakland Transit Consolidated, 1st consolidated Mortgage 5 per cent, $1,000 Gold Bond No. 4328............	1,040 00	
(Interest Jan. and July; principal due July 1, 1932.)		
Sunset Telephone and Telegraph Company, consolidated Mortgage 5 per cent, $1,000 Gold Bond No. 641......	1,084 02	
(Interest April and Oct.; principal due Oct. 1, 1929.)		3,501 37
Donohoe Comet-Medal Fund.		
With San Francisco Savings Union..................		792 66
Bruce Medal Fund.		
With Mutual Savings Bank...........................	$ 801 93	
Bay Counties Power Company, 1st consolidated Mortgage 5 per cent, $1,000 Sinking Fund Gold Bond No. 1636..	1,012 50	
(Interest March and Sept.; principal due Sept. 1, 1930.)		
The Edison Electric Company, Los Angeles, 1st and Refunding Mortgage 5 per cent, $1,000 Gold Bond No. 168	977 22	
(Interest March and Sept.; principal due Sept. 1, 1922.)		2,791 65
John Dolbeer Fund.		
With Union Trust Company..........................	$ 970 28	
South Pacific Coast Railway Company, 1st Mortgage 4 per cent guaranteed (by S. P. Co.), $1,000 Gold Bond No. 3407	1,000 00	
(Interest Jan. and July; principal due July 1, 1937.)		
Oakland Transit Consolidated, 1st consolidated Mortgage 5 per cent, $1,000 Gold Bond No. 4329.............	1,040 00	
(Interest Jan. and July; principal due July 1, 1932.)		
Bay Counties Power Company, 1st consolidated Mortgage 5 per cent, $1,000 Sinking Fund Gold Bond No. 1637.	1,012 50	
(Interest March and Sept.; principal due Sept. 1, 1930.)		
The Edison Electric Company, Los Angeles, 1st and Refunding Mortgage 5 per cent, $1,000 Gold Bond No. 169	977 22	
(Interest March and Sept.; principal due Sept. 1, 1922.)		5,000 00
William Alvord Fund.		
With Humboldt Savings Bank........................	$ 331 94	
With Savings & Loan Society........................	1,463 50	
Sunset Telephone and Telegraph Company, consolidated Mortgage 5 per cent, $1,000 Gold Bond No. 656, and $1,000 Gold Bond No. 657..........................	2,168 06	
(Interest April and Oct.; principal due Oct. 1, 1929.)		
Contra Costa Water Company, 5 per cent $1,000 Gold Bond No. 87	1,036 50	
(Interest Jan. and July; principal due Jan. 1, 1915.)		5,000 00
		$19,269 63

San Francisco, March 30, 1907.

Examined and found correct.

Charles S. Cushing, } Auditing
B. A. Baird, } Committee.

F. R. Ziel, *Treasurer.*

The report was, on motion, accepted and filed.

The President, in an informal address, briefly reviewed the condition of the Society, and then proceeded to speak on the results of statistics on the eccentricities of comet orbits, an extract of which appears in this number of the *Publications*.

Professor AITKEN gave an interesting talk on "Double Stars."

The thanks of the Society were returned to Messrs. CUSHING, GRANT & CUSHING, for the use of their rooms.

Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS HELD MARCH 30, 1907, AT 10 P.M.

The new Board of Directors was called to order by President LEUSCHNER. A quorum was present. The minutes of the last meeting were approved.

The business in hand being the election of officers for the ensuing year, the following officers, having received a majority of the votes cast, were duly elected:—

President: Mr. CHAS. S CUSHING.

First Vice-President: Mr. A. H. BABCOCK.

Second Vice-President: Mr. W. W. CAMPBELL.

Third Vice-President: Mr. GEO. E. HALE.

Secretary: Mr. R. T. CRAWFORD.

Treasurer: Mr. F. R: ZIEL.

Committee on the Comet-Medal: Messrs. W. W. CAMPBELL (*ex officio*), CHAS. BURCKHALTER, C. D. PERRINE.

Library Committee: Messrs. CRAWFORD, IRVING, TOWNLEY.

Mr. CRAWFORD was appointed Librarian.

The President was authorized to appoint the members of the Finance Committee, and made the following selections:—

Finance Committee: D. S. RICHARDSON (Chairman), WM. H. CROCKER, CHAS. BURCKHALTER.

The Committee on Publication is composed of Messrs. R. G. AITKEN, S. D. TOWNLEY, B. L. NEWKIRK.

The following resolution was adopted:—

WHEREAS, Mr. F. R. ZIEL retires from the office of Secretary of the Society after fifteen consecutive years of service;

Resolved, That the Directors hereby express their hearty thanks to Mr. ZIEL for the disinterested fidelity and the great efficiency of his services to the Society.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. CHAS. S. CUSHING .... *President*
Mr. A. H. BABCOCK .... *First Vice-President*
Mr. W. W. CAMPBELL .... *Second Vice-President*
Mr. GEO E. HALE .... *Third Vice-President*
Mr. R. T. CRAWFORD (Students' Observatory, Berkeley) .... *Secretary*
Mr. F. R. ZIEL .... *Treasurer*

Board of Directors—Messrs. AITKEN, BABCOCK, BURCKHALTER, CAMPBELL, CROCKER, CRAWFORD, CUSHING, HALE, RICHARDSON, TOWNLEY, ZIEL.

Finance Committee—Messrs. RICHARDSON, CROCKER, BURCKHALTER.

Committee on Publication—Messrs. AITKEN, TOWNLEY, NEWKIRK.

Library Committee—Messrs. CRAWFORD, IRVING, TOWNLEY.

Committee on the Comet-Medal — Messrs. CAMPBELL (ex-officio), BURCKHALTER, PERRINE.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 806 Franklin Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., Students' Observatory, Berkeley, Cal., who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," Students' Observatory, Berkeley, Cal., in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

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PUBLICATIONS

OF THE

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OF THE PACIFIC.

VOLUME XIX.

NUMBER 114.

1907.

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COMMITTEE ON PUBLICATION.

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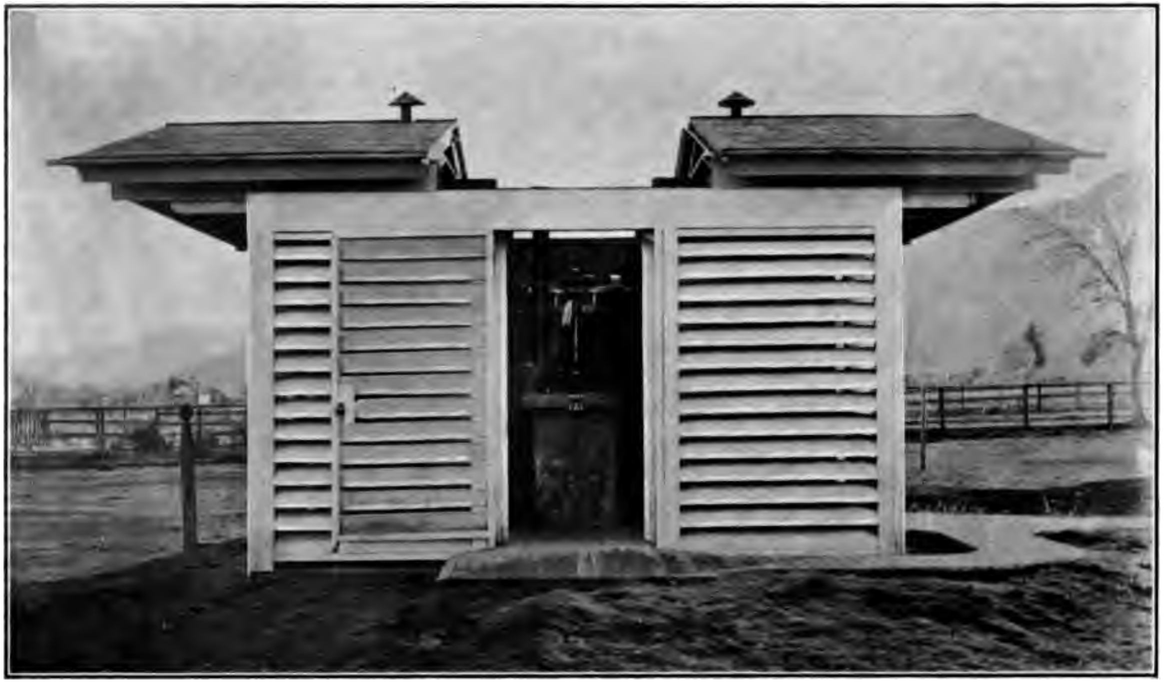
SIDNEY D. TOWNLEY, Ukiah, Cal.

BURT L. NEWKIRK, Mt. Hamilton, Cal



INTERNATIONAL LATITUDE OBSERVATORY, UKIAH, CALIFORNIA.
(LOOKING SOUTH.)

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XIX. SAN FRANCISCO, CALIFORNIA, JUNE 10, 1907. No. 114.

ECLIPSES AND TRANSITS OF THE SATELLITES OF *SATURN* OCCURRING IN THE YEAR 1907.

By HERMANN STRUVE.

In the present year the cycle of eclipses and transits of the satellites of *Saturn* extends over all satellites, including *Titan*, and it is to be hoped that this very favorable opportunity of observing these interesting phenomena will not be lost. I have therefore computed the approximate times and places of the eclipses and transits for every day from June 20, 1907, to January 17, 1908.

In the following tables are first collected the data for the eclipses and transits of *Titan*, phenomena which can be observed also with smaller instruments. It would be of particular interest to observe the eclipses of *Titan* with photometers, the long duration of the appearances of *Titan* giving sufficient time for photometric comparisons. In the case of *Titan* it happens that both phenomena, the disappearance and the reappearance, are visible on the same day from the Earth. The times given for the eclipses of *Titan* are the moments when the center of the satellite passes the shadow-cone from the center of the Sun. For the transits of the shadow and of the disk of *Titan* the times of their crossing the minor axis of the planet are computed, and also the semi-duration of the transits, giving the approximate times of their ingress and egress on the disk of *Saturn*. It is to be understood that the predicted times depend greatly on the assumed values of the diameters of the planet and may deviate several minutes from the truth. Careful estimations of the times when the shadow on the disk of *Titan* is first or last seen on the planet will be very valuable.

The tables of the eclipses of the other satellites are arranged in the same manner as in the preceding year.[1] For these satellites only the disappearances are visible before opposition and only the reappearances after opposition. The first column contains the day of the month, the second the eclipsed satellite, the third the Greenwich time of the disappearance or reappearance, the last column, headed *s* and *p*, the geocentric place of the satellite at the time of his eclipse,—i. e. the distance of the satellite from the limb of the planet, and the position-angle, counted from the north point of the minor axis of the disk. The duration of the appearances, occurring this year nearly centrally, may be, in the case of *Rhea* several minutes, in the case of *Tethys* and *Dione* about one minute, in the case of *Mimas* and *Enceladus* only a few seconds. The attention of astronomers who are in possession of powerful instruments is particularly directed to these phenomena. On account of the disappearance of the rings before July 26th and after October 4th, and of their minuteness in the interval between those dates, it seems however very likely that in this year also instruments of moderate size can take part in these interesting observations.

It would be of great value also to ascertain the times of disappearance and reappearance of the rings by watching the planet carefully some days before and after the predicted dates. The observation of the first disappearance, on April 17th, will escape on account of the nearness of the Sun, but the reappearances of July 26th and January 7th and the disappearance of October 4th can be well observed.

Finally are added the approximate Greenwich times, when the shadows of the satellites *Tethys, Dione, Rhea* cross the minor axis of the disk, together with their distances from the center of the disk at the time of conjunction.

In the present opposition *Hyperion* also will be eclipsed at the times of his superior conjunction; but as it is doubtful whether these eclipses can be observed with sufficient accuracy I have not thought it worth while to calculate their times.

In the preparation of the following tables I was kindly assisted by Dr. P. GUTHERICK.

ROYAL OBSERVATORY, BERLIN, March, 1907.

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[1] See these *Publications*, Vol. XVIII, p. 203.

DISAPPEARANCE AND REAPPEARANCE OF THE RINGS OF *SATURN.*

1907.	April 17.	Disappearance.	The Earth in the plane of the rings.
	July 26.	Reappearance.	The Sun in the plane of the rings.
	October 4.	Disappearance.	The Earth in the plane of the rings.
1908.	January 7.	Reappearance.	The Earth in the plane of the rings.

ECLIPSES OF *TITAN.*

s and *p* denote the geocentric place of *Titan* at the time of its eclipse, i. e. the distance from the limb of the planet, and the position-angle, counted from the north point of the minor axis to the west or to the east.

			Gr. M. T.	*s*	*p*	
1907.	June 7	Disapp.	1h 23m	15″.8	104°	West.
	June 7	Reapp.	7 0	1 .4	128	
	June 23	Disapp.	0 27	17 .1	105	
	June 23	Reapp.	6 14	2 .0	130	
	July 8	Disapp.	23 33	17 .0	106	
	July 9	Reapp.	5 26	1 .5	134	
	July 24	Disapp.	22 40	15 .5	106	
	July 25	Reapp.	4 37	0 .0	141	
	Aug. 9	Disapp.	21 49	12 .5	105	
	Aug. 25	Disapp.	21 0	8 .0	104	
	Sept. 10	Disapp.	20 13	2 .6	101	
	Sept. 27	Reapp.	1 9	2 .2	91	East
	Oct. 13	Reapp.	0 15	6 .9	85	
	Oct. 28	Reapp.	23 19	10 .6	82	
	Nov. 13	Reapp.	22 22	13 .0	81	
	Nov. 29	Disapp.	16 56	0 .9	71	
	Nov. 29	Reapp.	21 22	13 .8	82	
	Dec. 15	Disapp.	16 27	1 .9	77	
	Dec. 15	Reapp.	20 19	13 .0	83	
	Dec. 31	Disapp.	16 3	2 .0	84	
	Dec. 31	Reapp.	19 9	10 .8	87	
1908.	Jan. 16	Disapp.	15 51	1 .9	93	
	Jan. 16	Reapp.	17 48	7 .3	92	

SHADOW OF *TITAN* AND DISK OF *TITAN.*

Crossing the minor axis of the planet at the distance *y* from the center.

			Gr. M. T.	*y*		Semi-duration of transit.
1907.	June 15	Shadow	9h 56m	1″.9	South	3h.0
	June 15	Disk	16 2	6 .4	North	1 .7
	July 1	Shadow	9 5	1 .2	South	3 .0
	July 1	Disk	15 7	7 .0	North	1 .5
	July 17	Shadow	8 16	0 .5	South	3 .0
	July 17	Disk	13 48	7 .0	North	1 .6
	Aug. 2	Shadow	7 30	0 .2	North	3 .0
	Aug. 2	Disk	12 6	6 .3	North	2 .0
	Aug. 18	Shadow	6 43	0 .9	North	3 .0
	Aug. 18	Disk	9 51	5 .0	North	2 .5

			Gr. M. T.	y		Semi-duration of transit.
1907.	Sept. 3	Shadow	$5^h\ 59^m$	1″.6	North	$3^h.0$
	Sept. 3	Disk	7 42	3.2	North	2.8
	Sept. 19	Disk	5 14	1.3	North	3.0
	Sept. 19	Shadow	5 15	2.3	North	2.9
	Oct. 5	Disk	2 48	0.7	South	3.0
	Oct. 5	Shadow	4 33	2.9	North	2.9
	Oct. 21	Disk	0 31	2.2	South	2.9
	Oct. 21	Shadow	3 49	3.6	North	2.8
	Nov. 5	Disk	22 32	3.1	South	2.8
	Nov. 6	Shadow	3 5	4.3	North	2.6
	Nov. 21	Disk	20 46	3.4	South	2.8
	Nov. 22	Shadow	2 21	4.9	North	2.4
	Dec. 7	Disk	19 47	2.9	South	2.8
	Dec. 8	Shadow	1 34	5.5	North	2.1
	Dec. 23	Disk	19 2	1.8	South	2.9
	Dec. 24	Shadow	0 48	6.2	North	1.8
1908.	Jan. 8	Disk	18 42	0.2	South	3.0
	Jan. 8	Shadow	23 59	6.8	North	1.2
	Jan. 24	Disk	18 42	1.7	North	3.0
	Jan. 24	Shadow?	23 6	7.4	North	?

ECLIPSES OF THE INNER SATELLITES OF *SATURN*, 1907.

DISAPPEARANCE BEFORE OPPOSITION.

s and p denote the geocentric place of the satellite at the time of its disappearance, i. e. the distance from the limb of the planet, and the position-angle, counted from the north point of the minor axis to the west.

		Gr. M. T.	s	p
June 20	Mi	$0^h\ 42^m$	2″.3	91° West
	Rh	4 2	7.2	100
	Di	4 5	5.2	99
	En	8 36	3.2	96
	Te	20 29	3.9	94
	Mi	23 19	2.3	91
21	En	17 29	3.2	96
	Mi	21 56	2.3	91
22	Te	17 48	3.9	94
	Mi	20 33	2.3	91
	Di	21 46	5.2	99
23	Ti D	0 27	17.1	105
	En	2 22	3.2	96
	Ti R	6 14	2.0	130
	Mi	19 10	2.3	91
24	En	11 15	3.2	96
	Te	15 7	3.9	94
	Rh	16 28	7.3	100
	Mi	17 47	2.3	91
25	Di	15 28	5.2	99
	Mi	16 25	2.3	91
	En	20 9	3.2	96
26	Te	12 25	3.9	94
	Mi	15 2	2.3	91
27	En	5 2	3.2	96
	Mi	13 39	2.3	91
28	Di	9 10	5.2	99
June 28	Te	$9^h\ 44^m$	3″.9	94° West
	Mi	12 16	2.2	91
	En	13 55	3.2	96
29	Rh	4 55	7.4	100
	Mi	10 53	2.2	91
	En	22 48	3.2	96
30	Te	7 2	3.8	94
	Mi	9 30	2.2	91
July 1	Di	2 51	5.2	99
	En	7 41	3.1	96
	Mi	8 7	2.2	91
2	Te	4 21	3.8	94
	Mi	6 44	2.2	91
	En	16 34	3.1	96
3	Mi	5 21	2.2	91
	Rh	17 22	7.4	101
	Di	20 33	5.2	99
4	En	1 27	3.1	96
	Te	1 39	3.8	94
	Mi	3 58	2.2	91
5	Mi	2 36	2.2	92
	En	10 21	3.1	96
	Te	22 58	3.8	94
6	Mi	1 13	2.2	92
	Di	14 15	5.1	99
	En	19 14	3.1	96
	Mi	23 50	2.2	92

			Gr. M. T.		*s*	*p*
July	7	Te	20h	17m	3″.8	94° West
		Mi	22	27	2 .2	92
	8	En	4	7	3 .1	96
		Rh	5	49	7 .3	101
		Mi	21	4	2 .2	92
		Ti D	23	33	17 .0	106
	9	Ti R	5	26	1 .5	134
		Di	7	56	5 .1	99
		En	13	0	3 .1	96
		Te	17	35	3 .8	94
		Mi	19	41	2 .2	92
	10	Mi	18	18	2 .2	92
		En	21	53	3 .0	96
	11	Te	14	54	3 .7	94
		Mi	16	55	2 .2	92
	12	Di	1	38	5 .1	99
		En	6	47	3 .0	96
		Mi	15	33	2 .2	92
		Rh	18	16	7 .2	101
	13	Te	12	12	3 .7	94
		Mi	14	10	2 .2	92
		En	15	40	3 .0	96
	14	Mi	12	47	2 .2	92
		Di	19	20	5 .0	99
	15	En	0	33	3 .0	96
		Te	9	31	3 .7	94
		Mi	11	24	2 .1	92
	16	En	9	26	3 .0	96
		Mi	10	1	2 .1	92
	17	Rh	6	43	7 .0	101
		Te	6	50	3 .7	94
		Mi	8	38	2 .1	92
		Di	13	1	5 .0	99
		En	18	19	3 .0	96
	18	Mi	7	15	2 .1	92
	19	En	3	12	2 .9	96
		Te	4	8	3 .6	94
		Mi	5	52	2 .1	92
	20	Mi	4	30	2 .1	92
		Di	6	43	4 .9	99
		En	12	6	2 .9	96
	21	Te	1	27	3 .6	94
		Mi	3	7	2 .1	92
		Rh	19	10	6 .7	100
		En	20	59	2 .9	96
	22	Mi	1	44	2 .0	92
		Te	22	45	3 .5	94
	23	Mi	0	21	2 .0	92
		Di	0	25	4 .8	99
		En	5	52	2 .8	96
		Mi	22	58	2 .0	92
	24	En	14	45	2 .8	96
		Te	20	4	3 .4	94
		Mi	21	35	2 .0	92
		Ti D	22	40	15 .5	106
	25	Ti R	4	37	0 .0	141
		Di	18	7	4 .7	99
		Mi	20	12	2 .0	92
		En	23	38	2 .8	96
	26	Rh	7	37	6 .4	100
		Te	17	23	3 .3	94

			Gr. M. T.		*s*	*p*
July	26	Mi	18h	50m	1″.9	92° West
	27	En	8	31	2 .7	96
		Mi	17	27	1 .9	92
	28	Di	11	48	4 .6	99
		Te	14	41	3 .3	94
		Mi	16	4	1 .9	92
		En	17	25	2 .7	96
	29	Mi	14	41	1 .9	92
	30	En	2	18	2 .7	96
		Te	12	0	3 .2	94
		Mi	13	18	1 .8	92
		Rh	20	4	6 .2	100
	31	Di	5	30	4 .5	99
		En	11	11	2 .6	96
		Mi	11	55	1 .8	92
Aug.	1	Te	9	19	3 .1	94
		Mi	10	33	1 .8	92
		En	20	4	2 .6	96
	2	Mi	9	10	1 .8	92
		Di	23	12	4 .3	99
	3	En	5	57	2 .5	96
		Te	6	37	3 .0	94
		Mi	7	47	1 .8	92
	4	Mi	6	24	1 .7	92
		Rh	8	32	5 .8	100
		En	13	51	2 .5	96
	5	Te	3	56	2 .9	94
		Mi	5	1	1 .7	92
		Di	16	54	4 .1	98
		En	22	44	2 .4	96
	6	Mi	3	39	1 .7	92
	7	Te	1	15	2 .8	94
		Mi	2	16	1 .7	92
		En	7	37	2 .3	96
	8	Mi	0	53	1 .7	92
		Di	10	36	3 .9	98
		En	16	30	2 .3	96
		Rh	20	59	5 .4	100
		Te	22	33	2 .8	93
		Mi	23	30	1 .6	92
	9	Ti	21	49	12 .5	105
		Mi	22	7	1 .6	92
	10	En	1	24	2 .2	96
		Te	19	52	2 .7	93
		Mi	20	45	1 .6	92
	11	Di	4	17	3 .7	98
		En	10	17	2 .2	95
		Mi	19	22	1 .5	92
	12	Te	17	11	2 .6	93
		Mi	17	59	1 .5	92
		En	19	10	2 .2	95
	13	Rh	9	26	4 .9	99
		Mi	16	36	1 .5	92
		Di	21	59	3 .5	98
	14	En	4	3	2 .1	95
		Te	14	29	2 .5	93
		Mi	15	13	1 .5	92
	15	En	12	56	2 .0	95
		Mi	13	51	1 .4	92
	16	Te	11	48	2 .3	93
		Mi	12	28	1 .4	92

		Gr. M. T.	s	p
Aug. 16	Di	$15^h\ 41^m$	3″.3	98° West
	En	21 50	1 .9	95
17	Mi	11 5	1 .4	92
	Rh	21 53	4 .5	99
18	En	6 43	1 .8	95
	Te	9 7	2 .2	93
	Mi	9 42	1 .3	92
19	Mi	8 19	1 .3	92
	Di	9 23	3 .0	98
	En	15 36	1 .8	95
20	Te	6 25	2 .1	92
	Mi	6 57	1 .3	92
21	En	0 29	1 .7	95
	Mi	5 34	1 .3	92
22	Di	3 5	2 .8	97
	Te	3 44	2 .0	92
	Mi	4 11	1 .2	92
	En	9 23	1 .7	95
	Rh	10 21	3 .9	99
23	Mi	2 48	1 .2	92
	En	18 16	1 .6	95
24	Te	1 3	1 .9	92
	Mi	1 26	1 .2	92
	Di	20 47	2 .5	97
25	Mi	0 3	1 .1	92
	En	3 9	1 .5	95
	Ti	21 0	8 .0	104
	Te	22 22	1 .8	91
	Mi	22 40	1 .1	92
26	En	12 2	1 .4	95
	Mi	21 17	1 .1	92
	Rh	22 48	3 .4	98
27	Di	14 29	2 .3	97
	Te	19 40	1 .6	91
	Mi	19 55	1 .0	92
	En	20 56	1 .3	95
28	Mi	18 32	0 .9	92
29	En	5 49	1 .2	94
	Te	16 59	1 .5	91
	Mi	17 9	0 .9	92
30	Di	8 11	2 .0	96
	En	14 42	1 .2	94
	Mi	15 46	0 .8	92
31	Rh	11 16	2 .7	98
	Te	14 18	1 .4	91
	Mi	14 24	0 .8	92
	En	23 35	1 .1	94
Sept. 1	Mi	13 1	0 .7	92
2	Di	1 53	1 .8	96
	En	8 29	1 .0	94

		Gr. M. T.	s	p
Sept. 2	Te	$11^h\ 37^m$	1″.3	91° West
	Mi	11 38	0 .7	92
3	Mi	10 15	0 .7	92
	En	17 22	0 .9	94
4	Mi	8 53	0 .6	92
	Te	8 55	1 .1	90
	Di	19 35	1 .5	96
	Rh	23 43	2 .2	97
5	En	2 15	0 .8	94
	Mi	7 30	0 .6	92
6	Mi	6 7	0 .5	92
	Te	6 14	1 .0	90
	En	11 9	0 .7	94
7	Mi	4 44	0 .5	92
	Di	13 17	1 .2	95
	En	20 2	0 .7	94
8	Mi	3 22	0 .5	92
	Te	3 33	0 .8	90
9	Mi	1 59	0 .4	92
	En	4 55	0 .6	93
	Rh	12 11	1 .6	96
10	Mi	0 36	0 .4	92
	Te	0 52	0 .7	90
	Di	6 59	0 .9	95
	En	13 49	0 .5	93
	Ti	20 13	2 .6	101
	Mi	23 14	0 .3	92
11	Mi	21 51	0 .3	92
	Te	22 11	0 .5	89
	En	22 42	0 .4	93
12	Mi	20 28	0 .2	92
13	Di	0 41	0 .6	94
	En	7 35	0 .3	93
	Mi	19 5	0 .2	92
	Te	19 30	0 .3	89
14	Rh	0 39	0 .7	95
	En	16 29	0 .2	92
	Mi	17 43	0 .1	92
15	Mi	16 20	0 .1	92
	Te	16 48	0 .2	89
	Di	18 23	0 .3	94
16	En	1 22	0 .1	92
	Mi	14 57	0 .0	92
17	En	10 15	0 .1	92
	Mi	13 35	0 .0	92
	Te	14 7	0 .1	89
18	Di	12 5	0 .1	93
	Mi	12 12	0 .0	92
	Rh	13 6	0 .1	94
	En	19 9	0 .0	92

REAPPEARANCE AFTER OPPOSITION.

s and *p* denote the geocentric place of the satellite at the time of its reappearance, i. e. the distance from the limb of the planet, and the position-angle, counted from the north point of the minor axis to the east.

		Gr. M. T.	s	p
Sept. 17	Mi	$15^h\ 55^m$	0″.0	95° East
	Te	17 6	0 .0	90
18	Mi	14 32	0 .0	95
	Di	15 25	0 .0	93
	Rh	17 3	0 .0	93

		Gr. M. T.	s	p
Sept. 18	En	$21^h\ 49^m$	0″.0	92° East
19	Mi	13 9	0 .0	95
	Te	14 25	0 .0	90
20	En	6 43	0 .1	92
	Mi	11 47	0 .1	95

		Gr. M. T.		*s*	*p*
Sept. 21	Dî	9^h	7^m	0."2	92° East
	Mi	10	24	0 .1	95
	Te	11	44	0 .1	90
	En	15	36	0 .2	92
22	Mi	9	1	0 .2	95
23	En	0	29	0 .3	91
	Rh	5	31	0 .6	92
	Mi	7	39	0 .2	95
	Te	9	3	0 .3	89
24	Di	2	50	0 .4	92
	Mi	6	16	0 .2	94
	En	9	23	0 .4	91
25	Mi	4	53	0 .3	94
	Te	6	21	0 .5	89
	En	18	16	0 .4	91
26	Mi	3	30	0 .3	94
	Di	20	32	0 .6	91
27	Ti	1	9	2 .2	91
	Mi	2	8	0 .4	94
	En	3	9	0 .5	91
	Te	3	40	0 .6	89
	Rh	17	58	1 .2	91
28	Mi	0	45	0 .4	94
	En	12	3	0 .6	91
	Mi	23	22	0 .4	94
29	Te	0	59	0 .8	89
	Di	14	14	0 .9	91
	En	20	56	0 .7	91
	Mi	22	0	0 .4	94
30	Mi	20	37	0 .5	94
	Te	22	18	0 .8	89
Oct. 1	En	5	50	0 .8	91
	Mi	19	14	0 .5	94
2	Rh	6	26	1 .8	90
	Di	7	56	1 .2	90
	En	14	43	0 .8	91
	Mi	17	52	0 .6	94
	Te	19	37	1 .0	88
3	Mi	16	29	0 .6	94
	En	23	36	0 .9	90
4	Mi	15	6	0 .6	94
	Te	16	56	1 .1	88
5	Di	1	38	1 .4	90
	En	8	30	0 .9	90
	Mi	13	43	0 .7	94
6	Mi	12	21	0 .7	94
	Te	14	15	1 .3	88
	En	17	23	1 .0	90
	Rh	18	53	2 .3	89
7	Mi	10	58	0 .8	94
	Di	19	20	1 .6	89
8	En	2	16	1 .1	90
	Mi	9	35	0 .8	94
	Te	11	34	1 .4	88
9	Mi	8	13	0 .8	94
	En	11	10	1 .1	90
10	Mi	6	50	0 .9	94
	Te	8	53	1 .5	88
	Di	13	2	1 .9	89
	En	20	3	1 .2	90
11	Mi	5	27	0 .9	93

		Gr. M. T.		*s*	*p*
Oct. 11	Rh	7^h	21^m	2."9	88° East
12	Mi	4	5	0 .9	93
	En	4	57	1 .3	90
	Te	6	12	1 .7	88
13	Ti	0	15	6 .9	85
	Mi	2	42	1 .0	93
	Di	6	44	2 .2	88
	En	13	50	1 .3	89
14	Mi	1	19	1 .0	93
	Te	3	31	1 .8	87
	En	22	43	1 .4	89
	Mi	23	56	1 .0	93
15	Rh	19	49	3 .4	88
	Mi	22	34	1 .0	93
16	Di	0	26	2 .4	88
	Te	0	50	2 .0	87
	En	7	37	1 .5	89
	Mi	21	11	1 .0	93
17	En	16	30	1 .6	89
	Mi	19	48	1 .1	93
	Te	22	9	2 .0	87
18	Di	18	8	2 .6	88
	Mi	18	26	1 .1	93
19	En	1	24	1 .6	89
	Mi	17	3	1 .1	93
	Te	19	28	2 .2	87
20	Rh	8	16	3 .9	87
	En	10	17	1 .7	89
	Mi	15	40	1 .2	93
21	Di	11	51	2 .8	88
	Mi	14	18	1 .2	93
	Te	16	47	2 .3	87
	En	19	11	1 .7	89
22	Mi	12	55	1 .2	93
23	En	4	4	1 .8	88
	Mi	11	32	1 .3	93
	Te	14	6	2 .4	87
24	Di	5	33	3 .0	87
	Mi	10	10	1 .3	93
	En	12	57	1 .8	88
	Rh	20	44	4 .4	86
25	Mi	8	47	1 .3	93
	Te	11	25	2 .5	87
	En	21	51	1 .9	88
26	Mi	7	24	1 .3	93
	Di	23	15	3 .2	87
27	Mi	6	2	1 .4	93
	En	6	44	2 .0	88
	Te	8	44	2 .6	87
28	Mi	4	39	1 .4	93
	En	15	38	2 .0	88
	Ti	23	19	10 .6	82
29	Mi	3	16	1 .4	93
	Te	6	3	2 .7	87
	Rh	9	12	4 .9	85
	Di	16	57	3 .4	87
30	En	0	31	2 .1	88
	Mi	1	54	1 .5	93
31	Mi	0	31	1 .5	93
	Te	3	22	2 .8	87
	En	9	25	2 .1	88

		Gr. M. T.		s	p
Oct. 31	Mi	23h	8m	1″.5	93°East
Nov. 1	Di	10	39	3.5	87
	En	18	18	2.2	88
	Mi	21	46	1.5	93
2	Te	0	41	2.8	86
	Mi	20	23	1.6	93
	Rh	21	40	5.2	85
3	En	3	12	2.2	88
	Mi	19	0	1.6	92
	Te	22	0	2.9	86
4	Di	4	22	3.7	87
	En	12	5	2.3	88
	Mi	17	38	1.6	92
5	Mi	16	15	1.6	92
	Te	19	19	3.0	86
	En	20	59	2.3	88
6	Mi	14	52	1.7	92
	Di	22	4	3.8	87
7	En	5	52	2.4	88
	Rh	10	7	5.5	85
	Mi	13	30	1.7	92
	Te	16	38	3.1	86
8	Mi	12	7	1.7	92
	En	14	46	2.4	88
9	Mi	10	44	1.7	92
	Te	13	57	3.2	86
	Di	15	46	4.0	87
	En	23	39	2.5	88
10	Mi	9	22	1.8	92
11	Mi	7	59	1.8	92
	En	8	33	2.5	88
	Te	11	16	3.2	86
	Rh	22	35	5.7	85
12	Mi	6	36	1.8	92
	Di	9	29	4.1	86
	En	17	26	2.5	88
13	Mi	5	14	1.8	92
	Te	8	35	3.3	86
	Ti	22	22	13.0	81
14	En	2	20	2.6	88
	Mi	3	51	1.8	92
15	Mi	2	28	1.9	92
	Di	3	11	4.2	86
	Te	5	54	3.3	86
	En	11	13	2.6	88
16	Mi	1	6	1.9	92
	Rh	11	3	6.0	85
	En	20	7	2.7	88
	Mi	23	43	1.9	92
17	Te	3	13	3.4	86
	Di	20	53	4.3	86
	Mi	22	20	1.9	92
18	En	5	0	2.7	87
	Mi	20	58	1.9	92
19	Te	0	32	3.4	86
	En	13	54	2.7	88
	Mi	19	35	1.9	92
20	Di	14	35	4.4	86
	Mi	18	12	1.9	92
	Te	21	51	3.4	86
	En	22	47	2.7	88

		Gr. M. T.		s	p
Nov. 20	Rh	23h	31m	6″.2	85°East
21	Mi	16	50	1.9	92
22	En	7	41	2.8	88
	Mi	15	27	2.0	92
	Te	19	10	3.4	86
23	Di	8	18	4.4	86
	Mi	14	4	2.0	92
	En	16	34	2.8	88
24	Mi	12	42	2.0	92
	Te	16	29	3.5	86
25	En	1	28	2.8	88
	Mi	11	19	2.0	92
	Rh	11	59	6.3	85
26	Di	2	0	4.5	86
	Mi	9	56	2.0	92
	En	10	21	2.8	88
	Te	13	48	3.5	86
27	Mi	8	34	2.0	92
	En	19	15	2.8	88
28	Mi	7	11	2.0	92
	Te	11	7	3.5	86
	Di	19	42	4.5	86
29	En	4	8	2.8	88
	Mi	5	48	2.0	92
	Ti D	16	56	0.9	71
	Ti R	21	22	13.8	82
30	Rh	0	27	6.4	85
	Mi	4	25	2.0	92
	Te	8	26	3.5	86
	En	13	2	2.8	88
Dec. 1	Mi	3	3	2.0	92
	Di	13	25	4.5	86
	En	21	55	2.8	88
2	Mi	1	40	2.1	92
	Te	5	46	3.6	87
3	Mi	0	17	2.1	92
	En	6	49	2.9	88
	Mi	22	55	2.1	92
4	Te	3	5	3.6	87
	Di	7	7	4.5	86
	Rh	12	54	6.5	86
	En	15	42	2.9	88
	Mi	21	32	2.1	92
5	Mi	20	9	2.1	92
6	Te	0	24	3.6	87
	En	0	36	2.9	88
	Mi	18	47	2.1	92
7	Di	0	49	4.5	87
	En	9	29	2.9	88
	Mi	17	24	2.1	92
	Te	21	43	3.6	87
8	Mi	16	1	2.1	92
	En	18	23	2.9	88
9	Rh	1	22	6.5	86
	Mi	14	38	2.1	92
	Di	18	32	4.5	87
	Te	19	2	3.6	87
10	En	3	16	2.9	88
	Mi	13	16	2.1	92
11	Mi	11	53	2.1	92
	En	12	10	2.9	88

			Gr. M. T.		s	p
Dec.	11	Te	16h	21m	3".6	87° East
	12	Mi	10	30	2 .1	92
		Di	12	14	4 .5	87
		En	21	3	2 .9	88
	13	Mi	9	8	2 .1	92
		Te	13	40	3 .6	88
		Rh	13	50	6 .4	87
	14	En	5	57	2 .9	88
		Mi	7	45	2 .1	92
	15	Di	5	56	4 .5	88
		Mi	6	22	2 .1	92
		Te	10	59	3 .6	88
		En	14	50	2 .9	88
		Ti D	16	27	1 .9	77
		Ti R	20	19	13 .0	83
	16	Mi	4	59	2 .1	92
		En	23	44	2 .9	88
	17	Mi	3	37	2 .1	92
		Te	8	18	3 .6	88
		Di	23	39	4 .5	88
	18	Mi	2	14	2 .1	92
		Rh	2	18	6 .4	87
		En	8	37	2 .9	88
	19	Mi	0	51	2 .1	92
		Te	5	37	3 .6	88
		En	17	31	2 .9	89
		Mi	23	28	2 .1	92
	20	Di	17	21	4 .4	88
		Mi	22	6	2 .1	92
	21	En	2	24	2 .8	89
		Te	2	56	3 .5	88
		Mi	20	43	2 .1	92
	22	En	11	18	2 .8	89
		Rh	14	46	6 .3	87
		Mi	19	20	2 .0	92
	23	Te	0	15	3 .5	89
		Di	11	3	4 .4	89
		Mi	17	38	2 .0	92
		En	20	11	2 .8	89
	24	Mi	16	35	2 .0	92
		Te	21	34	3 .5	89
	25	En	5	5	2 .8	89
		Mi	15	12	2 .0	92
	26	Di	4	45	4 .3	89
		Mi	13	49	2 .0	92
		En	13	58	2 .8	89
		Te	18	53	3 .4	89
	27	Rh	3	13	6 .1	88
		Mi	12	27	2 .0	92
		En	22	52	2 .7	89
	28	Mi	11	4	2 .0	92
		Te	16	12	3 .4	89
		Di	22	28	4 .3	89
	29	En	7	45	2 .7	89
		Mi	9	41	2 .0	92
	30	Mi	8	18	2 .0	92
		Te	13	31	3 .3	89
		En	16	39	2 .7	89

			Gr. M. T.		s	p
Dec.	31	Mi	6h	56m	2".0	92° East
		Rh	15	41	5 .9	88
		Ti D	16	3	2 .0	84
		Di	16	10	4 .2	89
		Ti R	19	9	10 .8	87
1908						
Jan.	1	En	1	32	2 .6	89
		Mi	5	33	1 .9	92
		Te	10	51	3 .3	89
	2	Mi	4	10	1 .9	92
		En	10	25	2 .6	90
	3	Mi	2	47	1 .9	92
		Te	8	10	3 .3	90
		Di	9	52	4 .1	90
		En	19	19	2 .6	90
	4	Mi	1	25	1 .9	92
	5	Mi	0	2	1 .9	92
		Rh	4	9	5 .7	89
		En	4	12	2 .5	90
		Te	5	29	3 .2	90
		Mi	22	39	1 .9	92
	6	Di	3	34	4 .0	90
		En	13	6	2 .5	90
		Mi	21	16	1 .9	92
	7	Te	2	48	3 .2	90
		Mi	19	43	1 .9	92
		En	21	59	2 .5	90
	8	Mi	18	31	1 .9	92
		Di	21	17	3 .9	90
	9	Te	0	7	3 .1	90
		En	6	53	2 .4	90
		Rh	16	37	5 .5	90
		Mi	17	8	1 .9	92
	10	Mi	15	45	1 .9	92
		En	15	46	2 .4	91
		Te	21	26	3 .0	91
	11	Mi	14	22	1 .9	92
		Di	14	59	3 .8	91
	12	En	0	40	2 .3	91
		Mi	13	0	1 .8	92
		Te	18	45	3 .0	91
	13	En	9	33	2 .3	91
		Mi	11	37	1 .8	92
	14	Rh	5	5	5 .1	91
		Di	8	41	3 .6	92
		Mi	10	14	1 .8	92
		Te	16	4	2 .9	91
		En	18	27	2 .3	91
	15	Mi	8	51	1 .8	92
	16	En	3	20	2 .2	91
		Mi	7	28	1 .8	92
		Te	13	23	2 .8	91
		Ti D	15	51	1 .9	93
		Ti R	17	48	7 .3	92
	17	Di	2	23	3 .4	92
		Mi	6	6	1 .8	92
		En	12	14	2 .2	91
	18	Rh	17	33	4 .8	91

SHADOWS OF THE SATELLITES OF *TETHYS, DIONE, RHEA*.

Crossing the minor axis of the disk at the distance y from the center.

		Gr. M. T.	y	
June 21	Di	14h.7	0″.3	South
	Te	20 .8	0 .8	
22	Rh	12 .4	0 .5	
23	Te	18 .1	0 .8	
24	Di	8 .4	0 .2	
25	Te	15 .4	0 .7	
27	Rh	0 .8	0 .4	
	Di	2 .1	0 .2	
	Te	12 .7	0 .7	
29	Te	10 .0	0 .7	
	Di	19 .8	0 .1	
July 1	Te	7 .3	0 .7	
	Rh	13 .3	0 .3	
2	Di	13 .5	0 .1	
3	Te	4 .6	0 .6	
5	Te	1 .9	0 .6	
	Di	7 .2	0 .0	
6	Rh	1 .7	0 .2	
	Te	23 .2	0 .6	
8	Di	0 .9	0 .0	
	Te	20 .5	0 .6	
10	Rh	14 .2	0 .2	
	Te	17 .8	0 .5	
	Di	18 .6	0 .1	North
12	Te	15 .2	0 .5	South
13	Di	12 .3	0 .1	North
14	Te	12 .5	0 .5	South
15	Rh	2 .6	0 .1	
16	Di	6 .0	0 .2	North
	Te	9 .8	0 .5	South
18	Te	7 .1	0 .4	
	Di	23 .7	0 .2	North
19	Rh	15 .0	0 .0	
20	Te	4 .4	0 .4	South
21	Di	17 .4	0 .3	North
22	Te	1 .7	0 .4	South
23	Te	23 .0	0 .4	
24	Rh	3 .5	0 .1	North
	Di	11 .0	0 .3	
25	Te	20 .3	0 .3	South
27	Di	4 .7	0 .4	North
	Te	17 .6	0 .3	South
28	Rh	15 .9	0 .1	North
29	Te	14 .9	0 .3	South
	Di	22 .4	0 .4	North
31	Te	12 .2	0 .3	South
Aug. 1	Di	16 .1	0 .5	North
2	Rh	4 .4	0 .2	
	Te	9 .6	0 .2	South
4	Te	6 .9	0 .2	
	Di	9 .8	0 .5	North
6	Te	4 .2	0 .2	South
	Rh	16 .8	0 .3	North
7	Di	3 .5	0 .5	
8	Te	1 .5	0 .2	South
9	Di	21 .2	0 .6	North
	Te	22 .8	0 .1	South
11	*Rh*	5 .3	0 .4	North
Aug. 11	Te	20h.1	0″.1	South
12	Di	14 .9	0 .6	North
13	Te	17 .4	0 .1	South
15	Di	8 .6	0 .6	North
	Te	14 .7	0 .1	South
	Rh	17 .7	0 .4	North
17	Te	12 .0	0 .0	
18	Di	2 .3	0 .7	
19	Te	9 .3	0 .0	
20	Rh	6 .2	0 .5	
	Di	20 .0	0 .7	
21	Te	6 .6	0 .0	
23	Te	3 .9	0 .0	
	Di	13 .6	0 .7	
24	Rh	18 .6	0 .6	
25	Te	1 .2	0 .1	
26	Di	7 .3	0 .8	
	Te	22 .6	0 .1	
28	Te	19 .9	0 .1	
29	Di	1 .0	0 .8	
	Rh	7 .0	0 .6	
30	Te	17 .2	0 .1	
31	Di	18 .7	0 .9	
Sept. 1	Te	14 .5	0 .2	
2	Rh	19 .5	0 .7	
3	Te	11 .8	0 .2	
	Di	12 .4	0 .9	
5	Te	9 .1	0 .2	
6	Di	6 .1	0 .9	
7	Te	6 .4	0 .2	
	Rh	7 .9	0 .8	
8	Di	23 .8	1 .0	
9	Te	3 .7	0 .3	
11	Te	1 .0	0 .3	
	Di	17 .5	1 .0	
	Rh	20 .4	0 .8	
12	Te	22 .3	0 .3	
14	Di	11 .2	1 .1	
	Te	19 .6	0 .3	
16	Rh	8 .8	0 .9	
	Te	17 .0	0 .4	
17	Di	4 .9	1 .1	
18	Te	14 .3	0 .4	
19	Di	22 .6	1 .1	
20	Te	11 .6	0 .4	
	Rh	21 .2	0 .9	
22	Te	8 .9	0 .4	
	Di	16 .2	1 .2	
24	Te	6 .2	0 .5	
25	Rh	9 .7	1 .0	
	Di	9 .9	1 .2	
26	Te	3 .5	0 .5	
28	Te	0 .8	0 .5	
	Di	3 .6	1 .2	
29	Te	22 .1	0 .5	
	Rh	22 .2	1 .1	
30	Di	21 .3	1 .3	

		Gr. M. T.	*y*
Oct. 1	Te	$19^h.4$	$0''.5$ North
3	Di	15.0	1.3
	Te	16.8	0.6
4	Rh	10.6	1.1
5	Te	14.1	0.6
6	Di	8.7	1.3
7	Te	11.4	0.6
8	Rh	23.0	1.2
9	Di	2.4	1.3
	Te	8.7	0.6
11	Te	6.0	0.6
	Di	20.1	1.4
13	Te	3.3	0.7
	Rh	11.5	1.3
14	Di	13.8	1.4
15	Te	0.6	0.7
16	Te	21.9	0.7
17	Di	7.5	1.4
18	Rh	0.0	1.3
	Te	19.2	0.7
20	Di	1.2	1.4
	Te	16.6	0.7
22	Rh	12.4	1.4
	Te	13.9	0.8
	Di	18.9	1.5
24	Te	11.2	0.8
25	Di	12.6	1.5
26	Te	8.5	0.8
27	Rh	0.9	1.5
28	Te	5.8	0.8
	Di	6.3	1.5
30	Te	3.1	0.9
31	Di	0.0	1.6
	Rh	13.3	1.5
Nov. 1	Te	0.5	0.9
2	Di	17.7	1.6
	Te	21.8	0.9
4	Te	19.1	0.9
5	Rh	1.8	1.6
	Di	11.4	1.6
6	Te	16.4	1.0
8	Di	5.1	1.7
	Te	13.7	1.0
9	Rh	14.3	1.7
10	Te	11.0	1.0
	Di	22.8	1.7
12	Te	8.3	1.0
13	Di	16.5	1.7
14	Rh	2.7	1.8
	Te	5.6	1.1
16	Te	3.0	1.1
	Di	10.2	1.8
18	Te	0.3	1.1
	Rh	15.2	1.8
19	Di	3.9	1.8
	Te	21.6	1.2
21	Te	18.9	1.2
	Di	21.6	1.8
23	Rh	3.6	1.9
	Te	16.2	1.2
24	Di	15.3	1.9

		Gr. M. T.	*y*
Nov. 25	Te	$13^h.6$	$1''.3$ North
27	Di	9.0	1.9
	Te	10.9	1.3
	Rh	16.1	2.0
29	Te	8.2	1.3
30	Di	2.8	2.0
Dec. 1	Te	5.5	1.4
2	Rh	4.6	2.1
	Di	20.4	2.0
3	Te	2.8	1.4
5	Te	0.1	1.4
	Di	14.2	2.1
6	Rh	17.0	2.1
	Te	21.5	1.5
8	Di	7.9	2.1
	Te	19.8	1.5
10	Te	16.1	1.5
11	Di	1.6	2.1
	Rh	5.5	2.2
12	Te	13.4	1.5
13	Di	19.3	2.2
14	Te	10.7	1.6
15	Rh	18.0	2.3
16	Te	8.0	1.6
	Di	13.0	2.2
18	Te	5.4	1.6
19	Di	6.7	2.3
20	Te	2.7	1.6
	Rh	6.5	2.4
22	Te	0.0	1.7
	Di	0.4	2.3
23	Te	21.3	1.7
24	Di	18.1	2.3
	Rh	18.9	2.5
25	Te	18.6	1.7
27	Di	11.8	2.4
	Te	16.0	1.8
29	Rh	7.4	2.5
	Te	13.3	1.8
30	Di	5.5	2.4
31	Te	10.6	1.8
1908.			
Jan. 1	Di	23.2	2.5
2	Te	7.9	1.9
	Rh	19.9	2.6
4	Te	5.2	1.9
	Di	17.0	2.5
6	Te	2.6	1.9
7	Rh	8.3	2.7
	Di	10.7	2.6
	Te	23.9	2.0
9	Te	21.2	2.0
10	Di	4.4	2.6
11	Te	18.5	2.0
	Rh	20.8	2.7
12	Di	22.1	2.7
13	Te	15.8	2.1
15	Te	13.2	2.1
	Di	15.8	2.7
16	Rh	9.3	2.8
17	Te	10.5	2.1

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1907.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter...	July 2,	6^h	34^m	A.M.	
New Moon	" 10,	7	17	A.M.	
First Quarter...	" 18,	5	12	A.M.	
Full Moon	" 24,	8	30	P.M.	
Last Quarter...	" 31,	6	25	P.M.	
New Moon....	Aug. 8,	10^h	36^m	P.M.	
First Quarter..	" 16,	1	5	P.M.	
Full Moon.....	" 23,	4	15	A.M.	
Last Quarter..	" 30,	9	28	A.M.	

The Earth reaches aphelion—that is, reaches its greatest distance from the Sun—July 5th, 7 A.M. Pacific time.

There will be two eclipses during July. The first is *an annular eclipse of the Sun* on July 10th, not visible in the United States. The path of central eclipse begins in the South Pacific, crosses South America, and ends in the South Atlantic.

The second is *a partial eclipse of the Moon* on the evening of July 24th. The beginning of the actual eclipse is visible generally throughout North America except the northwest portion, and the end throughout North America except Alaska. The principal phases are as follows, Pacific time:—

Moon enters penumbra, July 24,	5^h	59^m	P.M.
Moon enters shadow..	7	4	P.M.
Middle of the eclipse..	8	22	P.M.
Moon leaves shadow...	9	41	P.M.
Moon leaves penumbra	10	46	P.M.

The maximum obscuration of the Moon is a little more than six tenths of the Moon's diameter.

Mercury on July 1st is an evening star, having passed greatest east elongation on June 27th, and sets about an hour and one half after sunset. It is therefore at this time in fine position for observation, but it soon draws too near the Sun to be seen, and passes inferior conjunction on the evening of July 24th, becoming a morning star. It then moves rapidly away from the Sun, reaching greatest west elongation (18° 51′) on August 12th. It then rises about an hour and one half before sunrise and will be an easy object in the morning twilight. By the end of the month it has nearly reached superior conjunction with the Sun.

Venus is still a morning star, rising 1^h 24^m before sunrise July 1st, 1^h 3^m August 1st, and less than half an hour before on August 30th. It cannot easily be seen by the naked eye much after the first week in August. By the end of that month it will nearly have reached superior conjunction with the Sun.

During the latter part of July and through August *Mercury, Venus, Jupiter,* and *Neptune* are all very close together in the early morning sky just above the eastern horizon, and a good many conjunctions occur. *Mercury* is in conjunction with *Jupiter* July 31st, 8 P.M., and with *Venus* at 5 A.M. on August 1st,—not very close approaches, *Mercury* being nearly 5° south in each case. Next, on August 1st, 9 A.M., *Venus* and *Jupiter* are in conjunction, *Venus* being only 18′ north of *Jupiter*. *Mercury* and *Jupiter* are again in conjunction on August 10th, *Mercury* 2° 5′ south.

Mars comes to opposition with the Sun July 6th, 7 A.M. Pacific time, and is then above the horizon during the entire night. On August 1st it is above the horizon until about 2 A.M., and on August 31st it sets about half an hour after midnight. During most of the period it is moving westward, having begun this motion on June 5th. From July 1st to August 13th it moves about 8°, going back along a line somewhat south of its eastward motion in the spring, and at the latter date it occupies a position among the stars 5° south of its position on April 18th. From August 13th it moves eastward again, making about 4° before the end of the month, on a line a little north of the preceding westward motion. It does not reach its minimum distance from the Earth until July 13th, a week after opposition, and throughout July its distance varies only a little more than two millions of miles. During August the distance increases by about ten millions, and by the end of the month the brightness will diminish perceptibly, but will still exceed that of any of the fixed stars.

Jupiter is still an evening star on July 1st, but sets less than an hour after sunset, and it will not be an easy object for naked-eye observation. It comes to conjunction with the Sun July 15th, 11 P.M., and becomes a morning star. On August 1st it rises about an hour before sunrise, and on August 31st nearly three hours before.

Saturn rises at about 11^h 30^m P.M. on July 1st, at about 9^h 30^m P.M. on August 1st, and before 7^h 30^m P.M. on August

31st. It moves about 7° westward and 1° southward in the constellation *Pisces*. On July 1st the Earth is below and the Sun above the plane of the rings, so that we still have the dark face of the rings toward us. About July 25th the plane of the rings crosses the Sun, and from then until October Sun and Earth are on the same side of the plane. The rings are seen nearly edgewise, the minor axis being in the maximum at the end of July not more than four per cent of the major in the apparent ellipse, and this will diminish as the Earth approaches the plane of the rings.

Uranus is in opposition to the Sun on July 3d, and is then above the horizon during the entire night. On August 1st it sets at about 2^h 40^m A.M., and at about 12^h 40^m A.M. on August 31st. During the two months it moves about 2° westward in the constellation *Sagittarius* north of the "milk-dipper." *Uranus* is not far from *Mars* throughout the two months, and is in conjunction with it twice,—on July 19th, when *Mars* passes 5° 18′ south of it, and again on August 24th, when *Mars* passes 4° 37′ south, the motion of *Mars* being westward on the first occasion and eastward on the second.

Neptune is in conjunction with the Sun on the morning of July 5th, and becomes a morning star.

REVIEW.[1]

Resultate des Internationalen Breitendienstes. Vol. I (1903), by Th. Albrecht. Vol. II (1906), by Th. Albrecht and B. Wanach. Centralbureau der Internationalen Erdmessung; neue Folge der Veröffentlichungen, Nos. 8 und 13.

In the latter part of 1899 six astronomical stations were established in the northern hemisphere for the purpose of making systematic observations for the latitude of each station in order to determine the variations in this quantity. Observations at the six stations have been carried on continuously since they were established without serious interruption from any cause, and are to be continued into the future for an indefinite period of time. This work is being prosecuted by the International Geodetic Association, which has headquarters at Potsdam, Germany. This association was formed for the purpose of conducting geodetic undertakings which are international in character. It is supported by the most prominent nations of the world, including nearly all the governments of Europe, the United States, the Argentine Republic, and Japan. The geodetic institutes of the various countries in which the latitude stations are located co-operate with the central station in carrying on this particular piece of work, the three stations in the United States being under the supervision of the Coast and Geodetic Survey.

Thus far the International Geodetic Association has pubished two volumes (under the title at the head of this review) giving the results of the observations for the variation of latitude. Volume I contains all of the observations made

[1] The writer of this review has endeavored to make it both popular and technical. It is hoped that the general reader may be able to get from it a general knowledge of the problems presented under the head of the variation of latitude and the methods by which they are attacked. It is hoped also that the professional astronomer or the student of astronomy who cares to look into the subject more carefully may be able to get from it a fair idea of the details of the processes involved. No attempt has been made by the reviewer to explain in detail the parts which are purely technical and not essential to a general understanding of the problems involved. In a number of places the language of the authors has been followed quite closely, but in no case is the translation literal enough to warrant the use of quotation-marks. For some of the opinions expressed, and for Figure 1, and for the computations under the theory of probabilities, the authors are in no wise responsible. In order to protect them, some of the statements, with which the reader might not agree, and for which the reveiwer alone is responsible, are followed by the letter *r* in parenthesis.

from the time the stations were established until January 4, 1902, and Volume II the observations obtained in the interval from January 5, 1902, to January 4, 1905. A third volume is in the course of preparation.

The contents of Volume I are presented under eight headings, which are indicated by italics in the following paragraphs.

Introduction.—The phenomenon of the variation of latitude was first detected in 1889 by Dr. KÜSTNER, astronomer in the Royal Observatory at Berlin. Various observations and investigations during the first half of the last decade of the nineteenth century established the reality and the nature of the phenomenon, and steps toward a systematic and thorough attack upon the problems presented were first taken by the International Geodetic Association in 1895.

In selecting the stations, social, hygienic, seismological, and meteorological, as well as mathematical, conditions were considered, the prime requisite being, of course, that all of the stations should have a fair proportion of clear nights at all seasons of the year. Seventeen different combinations of stations lying between latitudes $+36° 48'$ and $+44° 50'$, and including two combinations in the southern hemisphere on parallels $-33° 54'$ and $-33° 27'$, were considered. The parallel of $+39° 8'$ was finally chosen with the stations located in Japan, in Italy, and in the eastern and western parts of North America. Two other stations were subsequently added, one in Central Asia and the other in the central part of North America, at Cincinnati.

For the four stations first established—Mizusawa, Carloforte, Gaithersburg, and Ukiah—four new instruments exactly alike were constructed by WANSCHAFF in Berlin, 108^{mm} aperture, 130^{cm} focal length, 104 magnification. The instruments at Tschardjui and Cincinnati, by the same maker, are smaller, 68^{mm} aperture, 87^{cm} focus, and 81^{mm} aperture, 100^{cm} focus, respectively, both having 100 magnifying power.

The Horrebow-Talcott method[1] of observation was selected as the best suited for the purpose of determining the latitude.

[1] Descriptions of this method may be found in any work on practical or general astronomy. The following statements concerning the method may be of help to those who are not familiar with its details. In order to make a determination of the latitude by this method it is necessary to measure, by means of an eye-piece micrometer attached to the zenith-telescope, the *difference* of zenith-distance of two stars of known declination which culminate at nearly equal zenith-distances, one north of and the other south of the zenith. The telescope is set at the mean

Twelve groups of stars, each containing six pairs at small zenith-distances (not more than 24°) and two pairs at large zenith-distance (about 60°), were selected. The stars were chosen by Dr. KIMURA, astronomer in charge of the Japanese station at Mizusawa. The magnitudes of the stars lie between 4.0 and 7.4, and the intervals between their culminations vary between four and sixteen minutes.

Two groups extending over four hours are observed each night according to the following programme:—

Group.	R. A.	To be Observed From	To	Duration of Group.	Duration of Group Connection.
I	$0^h - 2^h$	Sept. 23	Dec. 6	74 days	35 days
II	2 – 4	Nov. 2	Jan. 4	64	29
III	4 – 6	Dec. 7	Jan. 30	55	26
IV	6 – 8	Jan. 5	Feb. 24	51	25
V	8 – 10	Jan. 31	Mar. 21	50	25
VI	10 – 12	Feb. 25	Apr. 15	50	25
VII	12 – 14	Mar. 22	May 11	51	26
VIII	14 – 16	Apr. 16	June 8	54	28
IX	16 – 18	May 12	July 9	59	31
X	18 – 20	June 9	Aug. 13	66	35
XI	20 – 22	July 10	Sept. 22	75	40
XII	22 – 24	Aug. 14	Nov. 1	80	40

of the zenith-distances of the two stars and the first to culminate will pass a little above or below the middle of the field of view. This distance from the middle of the field is measured by means of the micrometer. The instrument is then reversed about its vertical axis, without disturbing the setting, and the telescope will then point as far south as it did north of the zenith before reversal, or *vice versa*. The second star will then pass through the field of view as far below or above as the first star was above or below the center, and this distance from the center is again measured by means of the micrometer. The proper combination of the micrometer settings on the two stars gives the actual difference of their zenith-distances, which may be turned into arc measure, provided the value of one revolution of the micrometer-screw be known. The latitude, ϕ, of the place of observation is computed by means of the formula,

$$\phi = \tfrac{1}{2}(\delta_n + \delta_s) + \tfrac{1}{2}(m_n - m_s)R + \tfrac{1}{2}(l_n + l_s) + \tfrac{1}{2}(r_n - r_s),$$

in which the first term of the right-hand member of the equation represents one half the sum of the declinations of the two stars of the pair observed; the second term one half the difference of the zenith-distances of the two stars as measured by means of the micrometer; the third term a small correction for any change in the pointing of the telescope after reversal, detected by means of two very delicate levels attached to the telescope; and the last term a small correction for the *difference* in the atmospheric refraction affecting the rays of light coming from the two stars. It might be noticed that if the two stars are at *exactly* the same zenith-distance, and the instrument is reversed without disturbing the pointing, then the second, third, and fourth terms each become zero in the equation above, and the latitude is nothing other than the mean of the declinations of the two stars, or the declination of the zenith.

As two groups are observed each night, it is seen that each group will be observed both with the preceding and the following one, for lengths of time which vary between twenty-five and forty days. This interval is made to vary simply for the convenience of the observer, for by this means the observing time is made to come earlier in the evening during the winter months than during the summer months. In winter the observations lie between 7 P.M. and 1 A.M., in summer between 9 P.M. and 3 A.M. The time of beginning is never less than one and one-half hours after sunset, and the time of ending never less than one and three-quarter hours before sunrise. As the heating effects before sunrise are less pronounced than the cooling effects after sunset, it might perhaps have been wise to shift the whole programme a little further into the night. (*r*)

The observatory buildings at the six stations are of similar construction but differ somewhat in details. The one at Ukiah is three meters square, built of wood, with tin roof, and surrounded by an open slatwork construction which serves in some measure to protect the building within from the fierce rays of the summer sun. The roof is divided in the meridian-line and mounted upon rollers so that the two halves may be rolled apart, one to the east, the other to the west, giving a maximum opening of 1.8 meters. A small house to protect the meridian targets is located fifty-five meters north of the telescope.

Description of the Stations.—Detailed descriptions of the six stations and their surroundings are given, covering eight pages of the quarto volume. A few of the chief facts only will be mentioned here.

The city of Mizusawa (10,000 inhabitants) is situated on the principal Japanese island (Nippon), 466 kilometers north of Tokyo. The city lies in a north and south valley 180 kilometers long and five to fifteen kilometers wide. There are ranges of mountains to the east and to the west of the valley, the highest peak having an altitude of 2,200 meters. The valley is given largely to the cultivation of rice. The observatory is located about one kilometer south of the city. The number of earthquakes at Mizusawa is large, but the locality is not affected by these disturbances as much as some other portions of Japan. The zenith-telescope at this station was injured during the transport from Potsdam and the observations obtained with it

during the first year were subject to rather large errors. There are two observers at Mizusawa, Dr. H. Kimura and Dr. T. Nakano, who have served continuously since the observatory was established.

Tschardjui is located east of the southern end of the Caspian Sea in the Central Asian possessions of the Russian Government. The station lies nine and one-half kilometers northwest of the city and three kilometers from the left bank of the Amu Daria or river Oxus. The observatory is located on an oasis in a sand-waste traversed by many canals. There is a greater range in the annual temperature at this station than at any of the others. The early observations at Tschardjui did not show a satisfactory agreement among themselves. This was found to be due to a poor level and the use of oil illumination. Electric illumination was substituted and the level discarded. It might not be out of place to remark, parenthetically, that it is now generally admitted that the heat from oil-lamps may have a very injurious effect upon observations in which a high degree of precision is expected. Since a satisfactory electric illumination for intermittent work may be obtained by the use of any good make of ordinary dry cells, there seems to be no longer any excuse for using oil illumination for work with a zenith-telescope or altazimuth. (*r*)

Tschardjui is affected by very few earthquakes. The observations at this station are made by a single observer. Several have thus far taken part, and they have all been officers of the Russian army.

The Italian station has a very picturesque location on an old tower, San Vittorio, on the island of San Pietro, one kilometer southwest of the city of Carloforte. The tower is located on a peninsula on the east side of the island, so that the meridian of the observatory lies entirely over the Mediterranean Sea, with the exception of 260 meters to the north and 220 meters to the south, and anomalies in the refraction would seem to be absolutely excluded. The island is free from mountains, the highest point being 211 meters above sea-level. The altitude of the observatory is twenty-two meters. Carloforte has 8,000 inhabitants and can be reached from Cagliari, the chief city of Sardinia, in eight hours. The island is free from earthquakes, there having been only four in nearly four hundred years of any considerable intensity, and none of these destruc-

tive. The observations at this station are made by two observers, who alternate with the nights. Several changes in the staff have taken place thus far, but all its members have been Italian astronomers.

The Gaithersburg Observatory is located one kilometer south of the village of that name, which is thirty-three kilometers northwest of the city of Washington. The observatory has an altitude of 165 meters above sea-level; the surrounding country is hilly. Mr. EDWIN SMITH, of the Coast and Geodetic Survey, made the observations at this station during the first year; Dr. HERMAN S. DAVIS during the succeeding five years. The work is now in charge of Dr. FRANK E. ROSS.

After the parallel of 39° 8′ had been selected for the location of the latitude stations it was found that this parallel passed through the grounds of the observatory of the University of Cincinnati, and Professor J. G. PORTER, director of the observatory, volunteered to carry on observations if he were provided with an instrument. The observatory is located upon a hill, twenty meters higher than the surrounding country, eight kilometers northeast of the city, and two kilometers east of the Ohio River. The altitude of the observatory is 247 meters above sea-level. Thus far all of the observations, except a few during the summer months, have been made by Professor PORTER.

The California station is situated two kilometers south of the city of Ukiah, the county seat of Mendocino County. The observatory is located toward the western edge of one of the numerous small valleys in the Coast Range of mountains. The valley, which is traversed by the Russian River, is about fifteen kilometers long and from three to five kilometers wide, and surrounded by mountains of an average height of about 400 meters above the floor of the valley. The altitude of the observatory is 220 meters above sea-level. Up to May, 1903, the observations at this station were made by Dr. FRANK SCHLESINGER, now director of the Allegheny Observatory; since that time the work has been in charge of the writer of this review.

From a seismological point of view all of the American stations are favorably located. Although the Pacific Coast is well recognized as a region of seismic activity, yet the mountainous character of the country surrounding Ukiah seems to

afford a measure of protection from these disturbances. No earthquake since the observatory was established, not even the great shock of April 18, 1906, has been of sufficient intensity to in any way interfere with the progress of observations.

Instrumental Constants.—The most important constants to be determined in the case of a zenith-telescope are the angular value of one revolution of the micrometer-screw and the angular value of one space of the levels.

The pairs of stars have been so chosen that an error in the value of a revolution of the micrometer-screw will be eliminated from the mean of the latitude derived from each group. If the mean of the declinations of the stars of a pair, $\frac{1}{2}(\delta_n + \delta_s)$, is less than the latitude it must be increased by half the difference of the zenith-distances as measured by means of the micrometer. If $\frac{1}{2}(\delta_n + \delta_s)$ is greater than the latitude, then the micrometer correction is to be applied with a negative sign. If now the value of a revolution of the micrometer-screw used is too small, all of the micrometer corrections will be *numerically* too small, and hence latitudes in the first case above will all be too small, and in the second case all too large. Hence, if in any group the sum of the positive micrometer corrections is made equal to the sum of the negative corrections, the errors will be eliminated in the mean latitude as determined from that group. On account of the precession this elimination will hold only for a certain epoch, and the same group cannot therefore be used for an indefinite period. In the work of the International Geodetic Association the first selection of groups was used for six years, three years on either side of the epoch 1903.0.

The angular value of one revolution of the micrometer-screws was determined by the use of two methods, transits of polar stars at elongation, and measurement of differences of declination of stars as they come to the meridian. The second of these methods was used only at Cincinnati and Ukiah. The chief objection to it is that the results are affected by whatever errors may pertain to the declinations of the stars used. The first method, transits of polar stars at elongation, is theoretically preferable, but in practice gives results which show rather a large and unsatisfactory range. This is very likely due to the fact that the observer must assume either that the angle between the line of sight of the telescope and the vertical

remains unchanged during the progress of the observations, an hour, more or less, or that any changes in this angle are truthfully indicated by the readings of the latitude levels. Levels at their best are untrustworthy instruments, and in this case, since it is necessary for the observer to stand during the whole progress of the observations near the south end of the level tubes, it is easily conceivable that the heat from the observer's body may so affect the levels that a change in the reading of the bubbles may take place without any corresponding change in the pointing of the telescope, or *vice versa*. (*r*)

The value of one revolution of the micrometer-screw depends of course upon the temperature at which the determination is made. The range in temperatures at Carloforte and Ukiah is not sufficient to enable a good determination of the temperature coefficient to be made, and the observed values at the other stations depart rather widely from the theoretical values computed from the coefficients of expansion of brass and steel and the known values of one revolution of the screws. These differences are to be explained through the statement that the temperature coefficient evidently depends upon factors other than those just stated.

All of the screws were investigated for both progressive and periodic errors, either by observation of polar stars at elongation or by the use of auxiliary apparatus. Periodic errors of a sensible magnitude were found only for the instruments at Tschardjui and Carloforte. The screw of the Cincinnati telescope was found to be practically free from both progressive and periodic errors. The progressive errors of the screws at Carloforte and Gaithersburg were found to be considerably larger than the values obtained at Potsdam in tests applied before the instruments were shipped. The only explanation seems to be that the screws were damaged in some way during transportation.

The values of the spaces of the latitude levels were determined by micrometric settings upon the mire or by the use of a level-trier. At Ukiah a new method of observing stars of nearly the same declination was tried by Dr. SCHLESINGER with good success. This method has certain decided advantages and the details of it have already been explained in these *Publications* (Vol. XIII, p. 13). The effect of temperature and barometric pressure on the levels was not investigated.

Instrumental Errors.—Before making observations for latitude with a zenith-telescope it is necessary to so adjust the instrument that any instrumental errors which may remain shall be so small that they will not have an appreciable effect upon the accuracy of the results to be obtained. In order to attain this end the vertical axis must be made truly vertical, or very nearly so, the horizontal axis truly horizontal and in the plane of the prime vertical and the collimation zero, or rather of the same magnitude as the flexure of the horizontal axis, in order that the one may counteract the other, or that the collimation minus the flexure may be nearly zero. The position of the axes may be tested by means of the levels attached to the instrument and by the mire. The collimation, flexure, and position of the meridian targets can be tested only by observations of the stars for time. Since the telescope in this type of instrument is attached to one end of the horizontal axis and a counterpoise of equal weight at the other end, the flexure of the horizontal axis is large, about two seconds of time, and a time determination with this instrument involves a laborious process unless the flexure be assumed as a known quantity.

Volumes I and II give the daily values of the instrumental errors for each station.

Atmospheric Conditions.—Observations of the inside and the outside temperature and of the barometric pressure are made hourly during the progress of observations. The only use to be made of these would be in the investigation of possible cases of abnormal refraction. It is the *difference* of the refraction of the two stars of a pair which enters into the computation of the latitude, and under normal conditions this may be computed for stars at small zenith-distances by means of a formula based upon a mean value of the temperature and the barometric pressure.

In addition to the individual temperature and barometric readings there is given a tabulation showing the mean temperature for each group connection at each station. The greatest range, 35°.6 centigrade, is at Tschardjui, the least at Carloforte and Ukiah, 13°.7 and 14°.8 respectively. The range in group-connection means is, from —8° to +21° at Mizusawa, from —9° to +26° at Tschardjui, from +10° to +23° at Carloforte, from —5° to +23° at Gaithersburg, from —4° to +24° at Cincinnati, from +4° to +19° at

Ukiah. At the last-named place, although the midday temperature often reaches 40° (104° Fahrenheit), and at times has reached as high as 45° (113° Fahrenheit), yet the temperature decreases rapidly immediately after sundown, and such a thing as a hot night is practically unknown.

Results of Observations.—The individual values of the latitude from each pair observed, computed by means of the equation already given, are found in tabular form in this section. The total number of determinations made during the period covered by the first volume is 27,387. The percentage of nights upon which observations were obtained at the various stations is as follows:—

Mizusawa	48 per cent.
Tschardjui	33 "
Carloforte	70 "
Gaithersburg	48 "
Cincinnati	34 "
Ukiah	47 "
Average	47 per cent.

The conditions at Carloforte, in the Mediterranean Sea, must be almost ideal from an astronomical standpoint, still the above tabulation cannot be taken as a true index of the weather at the stations. At Carloforte and at Mizusawa two observers are constantly employed, and probably nearly every favorable night is utilized. At the other stations, where all of the observations are made by a single observer, many favorable nights must of necessity be allowed to pass. At Ukiah, for instance, the percentage could be increased by at least ten, perhaps fifteen, if two observers were employed. In considering the above table the further fact should be taken into consideration that Professor PORTER, who makes the observations at Cincinnati, has many other duties in connection with his position as director of the Cincinnati Observatory and professor of astronomy in the University of Cincinnati. With him observing for latitude is an avocation and not a vocation. We should also consider the still further fact that at some stations,—for instance, Mizusawa,—many nights are rendered incomplete by fog or clouds, and a night upon which only one pair is obtained enters into the above tabulation with the same weight as a complete night of sixteen pairs. During the 750 days since observations

were begun at the last station to start, Mizusawa, there were only five upon which observations were obtained at all six stations.

Determination of the Definitive Latitudes.—The first investigation undertaken under this heading was to determine whether or not there was a systematic difference between observations taken east-west and those taken west-east. None of significance was found except at Mizusawa, in November and December, 1900. Only the seventy-two latitude pairs were used in the definitive determination of the latitude.

The next step was to determine corrections to the declinations of the stars from the observations themselves. There are two steps in this process,—first, to determine the reductions to be applied to the results of each pair in order to reduce them to a mean declination system of the group; second, the determination of the reductions necessary to bring the groups to a common basis. The first step was accomplished by taking the mean of the results from the six zenith pairs on each night that the complete group was observed, and then subtracting the individual results, including those for the two refraction pairs, from this mean. The results for each pair at each station were then collected and the grand means taken as the corrections to $\frac{1}{2}(\delta_n + \delta_s)$ for each pair.

The total mean error of the results will be made up of the accidental errors of observation and the systematic station errors, which last are either instrumental or personal, or perhaps of an external nature, such as anomalous refraction. The numerical value of the first of these, the accidental error of observation, may, on account of the richness of the observational material, be computed from the individual observations of a pair, thus eliminating all consideration of the errors of declination. The mean error for a single observation of a pair is about $\pm 0''.15$. The total mean error of the station mean for a single pair is $\pm 0''.067$ for the latitude pairs, and $\pm 0.''090$ for the refraction pairs. These values are greater than those to be obtained from the accidental errors alone, showing that there are in fact systematic station errors. It is not possible as yet to state what these are due to, but an examination of the ten pairs having the largest differences of zenith-distance seems to show that they may lie in errors in the assumed values of the micrometer-screws.

The corrections to the group means were applied to the mean group latitudes and the results assembled on pages 121-125. From these, differences between the group results for each group connection were obtained for each station and the results collected. After the weighted means for the six stations had been taken, it was found that their algebraic sum differed appreciably from zero. One explanation of this, and perhaps the most probable, is that the value of the constant of aberration used in the star-place reductions was in error. It was found that a correction to the aberration of $+0''.042$ would cause the "Schlussfehler"—closing error—to disappear. This would change the adopted constant of aberration from $20''.470$ to $20''.512$, a change which is confirmed by other investigations entirely separate from this. It might be stated here that the computations given in volume II cast some doubt upon the reality of this correction.

From the group differences the corrections to each group were formed which are necessary to reduce the twelve groups to a common declination system based on the declinations of the seventy-two latitude pairs. From these reductions to a mean system and the reductions to the group means the final corrections to the declinations of each pair were formed and collected into a table (page 129). These corrections were then applied to the daily means at each station, and these then formed into the group combination means, the latitude pairs and the refraction pairs being treated separately.

Determination of the Path of the Pole.—The path of the pole was determined from the normal values of the latitude for each group connection. The first step in this process was to determine the mean value of the latitude for each station, and this was done by a method of successive approximations. The differences between the mean values and the individual mean group connection values were then formed and plotted with time as the x co-ordinate. A mean curve was drawn for each station and then the values of $\phi - \phi_0$ (ϕ_0 being the mean latitude of the station) were read from it for each tenth of a year, thus eliminating in a large measure the errors of observation.

It was first assumed that the motion of the pole could be represented by an equation of the form,

$$\Delta\phi = x\cos\lambda + y\sin\lambda,$$

in which $\Delta\phi = \phi - \phi_0$, λ the longitude of the place of observation west of Greenwich, x and y the rectangular co-ordinates of the instantaneous pole in a system the origin of which is located at the position of the mean pole, the x axis of which points toward Greenwich, and the y axis toward a point in 90° west longitude. The above equation may be derived easily from the following figure.

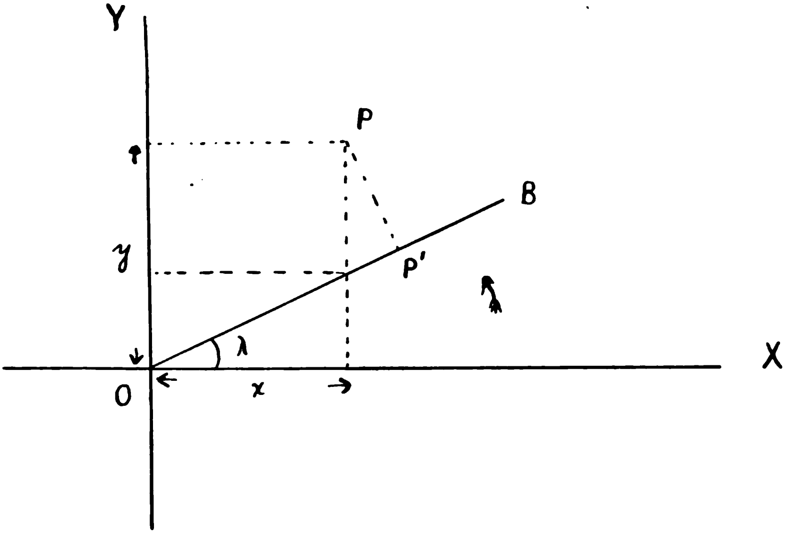

FIG. I.

Let $O B$ be the direction toward any observatory in west longitude λ, P the instantaneous position of the pole, and P' the foot of the perpendicular dropped from P upon $O B$. Then we have,

$$
\begin{aligned}
O P' = \Delta\phi &= x \sec\lambda + (y - x \tan\lambda) \sin\lambda, \\
&= x \left(\sec\lambda - \frac{\sin^2\lambda}{\cos\lambda} \right) + y \sin\lambda, \\
&= x \cos\lambda + y \sin\lambda.
\end{aligned}
$$

Early investigations showed that the observations were not satisfied very well by this equation, and Dr. KIMURA suggested the introduction of a third unknown independent of the longitude, thus,

$$\Delta\phi = x \cos\lambda + y \sin\lambda + z.$$

Least-square solutions under both assumptions were made, the one involving the solution of six equations for two unknowns

at each tenth of a year, the other the solution of six equations for three unknowns at each tenth of a year. The sum of the weighted squares of the residuals is so measurably better under the second assumption that there seems to be no doubt about the existence of the term z. The largest residuals were found in the case of Gaithersburg, and they were so much larger than the others that the case seemed to demand special investigation. The period under discussion involved a change of observers at Gaithersburg, SMITH leaving at the close of 1900. The two observers, however, did not observe together long enough to determine their personal equation. It was found that the large residuals at Gaithersburg could be greatly reduced by *assuming* a personal equation of a tenth of a second,—namely, ϕ Davis — ϕ Smith $= +0''.10$. Upon the introduction of corrections based upon this assumption the residuals for Gaithersburg, and also for Cincinnati, were reduced to the same order of magnitude as those of the other stations. The difference between the results obtained by two observers lies perhaps not so much in the bisections of the stars as in the general handling of the instrument, especially, in the opinion of the reviewer, in the manipulation of the levels.

The final values of x and y give the motion of the pole as represented in the first part of the curve of Figure II, reprinted from these *Publications*,[1] and showing also the motion of the pole as obtained from subsequent observations up to the beginning of 1906.

It is not possible to decide from the data at hand whether or not the values of z derived for these stations hold also for other latitudes. The question can be most easily decided by establishing latitude stations in the southern hemisphere, and this has now been done. Three explanations are offered by Dr. ALBRECHT in regard to the term z—anomalous refraction, a north and south oscillation of the center of gravity of the Earth, the effect of the neglected annual parallax of the fixed stars. The values of z for the six different stations were found to be practically the same, so that the hypothesis of anomalous refraction seems to be excluded.

Volume II.—The second volume contains the presentation of all the observations made between 1902, January 5th, and 1905, January 4th. The treatment in this volume is in all

[1] Vol. XVIII, No. 111, p. 315.

respects similar to that given in Volume I, except that the section on the description of the observatories is omitted and a section is added at the end under the heading, "Derivation and Discussion of the Results of the Refraction Pairs." It

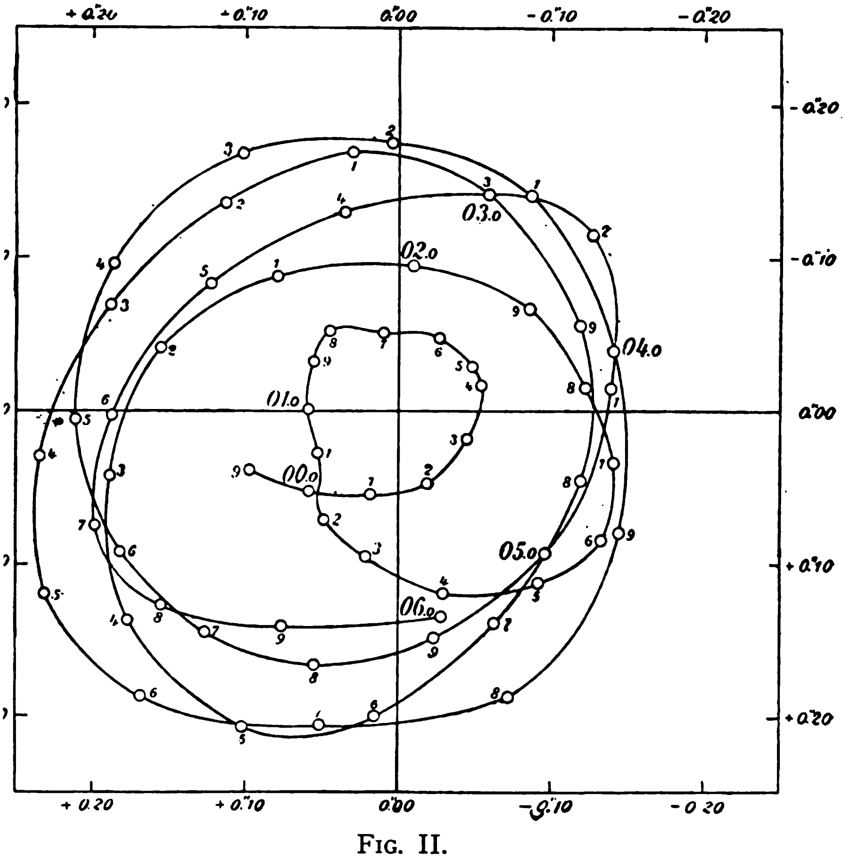

FIG. II.

is intended to call attention here only to those points at which something new is brought out in the second volume.

Additional observations were made at all of the stations for values of one revolution of the micrometer-screws, and an attempt was made to determine the temperature coefficients. As before stated, these were determined at all of the stations except Carloforte and Ukiah, where the range of temperatures is not sufficiently great to enable a good determination to be

made. Since all of the instruments were made by one maker, after the same pattern, differing only in size, it was decided to assume that the temperature coefficient was the same for all. From the observations for the four instruments for which determinations have been made, the weighted mean temperature coefficient, the change per degree centigrade per second of arc of the micrometer-screw, was found to be — 0.0000259, and the resulting values for the six screws are then easily found. Before the final results for Volume II were worked out, corrections to the observed values of one revolution of the micrometer-screws were determined from the latitude observations themselves. These corrections lie between — 0.0009, for Gaithersburg, and — 0.0251, for Tschardjui.

The total number of observations obtained during the period under consideration in the second volume is 36,173. The percentage of nights upon which observations were made is 46.5, almost exactly the same as during the period covered by Volume I. There was an increase in the percentage at four of the stations and a decrease at Gaithersburg and Cincinnati. The percentage at Carloforte increased from 70 to 73.

During the interval under consideration, 1,096 days, there were only fourteen evenings on which observations were obtained at all six stations, and on three of these only one pair was obtained at some stations. There was not a single evening on which a complete programme was obtained at all six stations, and by looking back into Volume I it is found that there has not been a single night, from the time the last station started, 1899, December 16th, to 1905, January 4th, 1,846 nights, upon which a complete programme was obtained at all six stations.

This seems a little strange at first thought, but a simple computation according to the principles of probability will show that we are here dealing with a very rare event. Let us ask, first, What is the probability of obtaining at least some observations at each station on the same night? If we assume that observations are made on the average on fifty per cent of the nights, then the probability of obtaining observations at any one station on any particular night will be one half, and manifestly the probability of obtaining observations at two stations on the same night will be $\frac{1}{2} \times \frac{1}{2}$, or $\frac{1}{4}$, and the probability of obtaining observations at three stations on the

same night $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$, and the probability of obtaining observations at six stations $(\frac{1}{2})^6 = {}^1/_{64}$. Observations would therefore be made at all six stations on the same night on an average of once in every sixty-four nights. Our assumption, however, that observations are made upon fifty per cent of the nights is somewhat in error, the true percentage being almost exactly 46.5. The probability of this event occurring would be therefore $({}^{465}/_{1000})^6$ which equals ${}^1/_{99}$. This event would occur on an average therefore of once in every ninety-nine days, or nineteen times during the 1,846 days under consideration.[1] This result is in exact agreement with the observed number; there were five such events during the period covered by Volume I and fourteen during the period covered by Volume II. (*r*)

Let us now ask, What is the probability of obtaining a complete night's work at all six stations on any particular night? The ratio between the number of complete nights and the total of nights observed is not given in the volumes, but it is probably not far from one half. At Ukiah about sixty per cent of the nights upon which observations are made are complete, but the percentage is known to be less at some of the other stations. If now we assume that observations are made upon fifty per cent of the nights, and fifty per cent of these are complete, then the same kind of reasoning that was used before will bring us to the conclusion that the probability of the occurrence of the event under consideration is $({}^1/_{64})^2 = {}^1/_{4096}$. That is to say, a complete night's work will be obtained at all six stations on an average, in round numbers, of once in every 4,000 nights, or once in about eleven years, so that it is not at all surprising that this rare event did not occur at all during the first five years of observations. (*r*)

The mean errors of a single determination of the latitude are practically identical for all stations except Carloforte, which seems to show that as accurate observations can be made with the small instruments at Tschardjui and Cincinnati as with the larger ones. The observations made at Carloforte stand in a class by themselves, as far as accidental errors go, these being distinctly less than at the other stations, probably largely

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[1] The exact method of computing this probability is, of course, to take the product of the six separate probabilities rather than the sixth power of the average probability. The result comes out sixteen, rather than nineteen.

due to the favorable meteorological conditions. An examination of the curves represented in Figure 3 shows, however, that notwithstanding the small accidental errors and the large number of observations obtained at Carloforte the final results for this station are not as accurate as for some of the other stations,—Mizusawa, for example,—where the taking of ob-

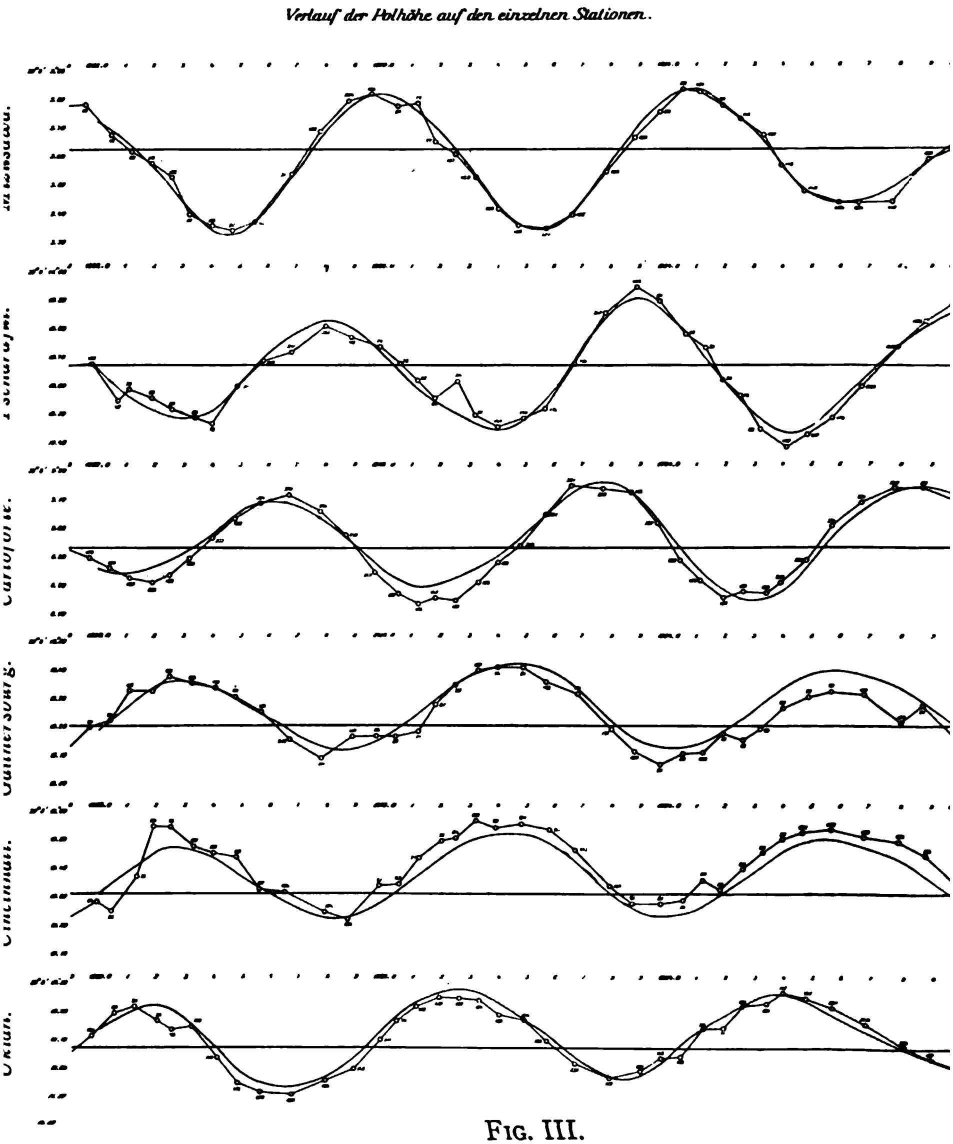

FIG. III.

servations is often badly interfered with on account of clouds or fog. Nearly twice as many observations are obtained at Carloforte as at Mizusawa, and this is a good illustration of the precept that little or nothing is to be gained by increasing beyond a certain moderate amount the number of observations made with the same instrument under similar circumstances. Perhaps just as good results could be obtained by limiting the number of observations at each station to 1,200 or 1,500 a year. (*r*)

In explanation of Figure III it should be stated that the small circles represent the average observed latitude for certain intervals, the small numbers adjacent to the circles indicating the number of observations entering into the average. After the results were all combined and the most probable values of x, y, and z were obtained from the least-square solutions, as already explained, the values of x and y were computed for each station at certain times and the results plotted on the same figure with the observed curves, producing the smooth curves of Figure III. The amounts by which the circles depart from the smooth curves, the residuals, are probably very close to the true errors of observation, and that station in which these residuals are the smallest has, of course, procured the best results.

The "closing errors" vary so much more in the different years for the same station than should be expected from the accidental errors, that it seems necessary to conclude that these differences cannot be all laid up to an erroneous value of the aberration constant. It would be necessary to assume the constant of aberration equal to $20''.541$ in order to completely explain away the closing errors. The differences are perhaps due to meteorological causes,—a very handy explanation.

The quantities z, as derived in the second volume, show a tendency toward a change in a positive direction, which presumably is due to uncertainties concerning the knowledge of the proper motions of the stars observed. An average change of $+0''.016$ a year in the proper motions would cause the positive tendency in z to disappear. The evidence seems to show that we have in this quantity z a term of constant amplitude and a period of a year. The observations thus far, however, give no indication of the cause of this term.

Volume II is concluded with a discussion of the results obtained from the observations of pairs at large zenith-distances, the so-called refraction pairs. Several hypotheses concerning abnormal refractions were made, but no very definite conclusions concerning them could be drawn from the data at hand. Without taking up the details it is perhaps sufficient to state the general conclusion reached by the authors, and that is, that observations at 60° zenith-distance provide no evidence whatever from which conclusions can be drawn regarding refractive perturbations at small zenith-distances. The observation of refraction pairs was therefore discontinued at the beginning of 1906.

SIDNEY D. TOWNLEY.

NOTES FROM PACIFIC COAST OBSERVATORIES.

The Results of an Effort to Determine Motion within the Solar Corona.[1]

The existence of material in the corona, at various distances from the Sun, implies that it has come from somewhere, no doubt very largely, or even almost exclusively, from the Sun itself. The changed coronal forms and structures observed at different eclipses are further evidence that motion occurs. Is the material moving out from the Sun, or toward the Sun, or both? Accurate observational knowledge on this subject is very meager.

At the eclipse of 1901, favorable conditions existed in the corona for determining velocities. Measures of short-exposure negatives taken near the beginning and end of totality by the Crocker Expedition to Sumatra showed no displacements of coronal masses in the interval of a little more than five minutes.[2]

Considering the accuracy of measurement, a velocity of twenty miles per second across the line of sight should have been detected with certainty, and motions should have been suspected had they been as great as twelve or fifteen miles per second.

The unusually favorable eclipse of August 30, 1905, afforded a hope that large-scale photographs of the corona secured in Labrador, Spain, and Egypt, or in two of these countries, would enable us to detect changes in the coronal structure occurring in the long intervals between the times of totality in those countries. Such photographs were obtained by the Crocker expeditions to Spain and Egypt, cloudy weather having prevailed in Labrador. The Spanish plates were secured by Messrs. Campbell and Perrine, with the assistance of Dr. R. S. Dugan and Professor Felipe Lavilla; and the

[1] From *Lick Observatory Bulletin*, No. 115.

[2] *Lick Observatory Bulletin*, Vol. I, 152, 1902.

Egyptian plates by Professor HUSSEY, with the assistance of the late Professor ROBERT H. WEST and Mr. H. T. R. DRAY. Totality occurred seventy minutes later in Egypt than in Spain.

We have made careful comparison of the coronal images obtained at the two stations. A number of fairly well-defined nuclei existed both east and west of the Sun. Details of structure within the nuclei appeared to change, but the nuclei as a whole seemed to remain in the same positions. Measures of great accuracy cannot be made, principally because the poorer seeing in Egypt affected the definition; but we are able to say that the masses in question could not have moved so much as one mile per second during the interval of 4,200 seconds. Greater speeds might well have occurred within the principal coronal streamers, or within some of the arched forms which inclose prominences, without our having detected them; for their structure is quite uniform, and well-defined nuclei are absent. Thus, in the structures where higher speeds should perhaps be most naturally expected, photographic methods have little chance to detect them. However, it is not improbable that at some future eclipse well-defined nuclei in coronal streamers will exist and be recorded at two or more stations.

Our result is in harmony with ARRHENIUS's view of coronal origin: "It is very probable that those drops for which gravitation is just compensated by the pressure of radiation will be the chief material of the inner corona. For drops of other sizes are selected out, the heavier ones by falling back to the Sun, the lighter ones by being driven away by the pressure of radiation, so that the drops which, so to say, swim under the equal influence of gravitation and pressure of radiation will accumulate in the corona."[1]

Assuming that motions of appreciable size exist within the corona, it should be said that the spectrographic method of determining them is unpromising, for several reasons. The exposures are from necessity short, and the coronal light is intrinsically weak. The brighter parts of the corona radiate light forming a continuous spectrum, neglecting the almost insignificant component which gives rise to bright lines, and the relatively small quantity of reflected photospheric light.

[1] ARRHENIUS, *Lick Observatory Bulletin*, Vol. II, 190, 1904.

Spectrograms of the middle and outer corona, obtained with a relatively wide slit and low dispersion, record the Fraunhofer lines but faintly. A spectrogram of good strength would probably be difficult and uncertain in interpretation, as the slit of the spectrograph would receive light from streamers which radiate in a variety of directions from the Sun. Recalling that a reflecting particle moving directly from the Sun toward the observer will not displace the spectrum lines at all; that a reflecting particle moving directly away from, or directly toward, both Sun and observer, will give double displacement of the lines toward the red or toward the violet, respectively; and that the coronal light falling upon the slit is from particles possessing a great variety of motions between these limits; the complexity of the result is evident.

All the spectrographic measures of motion within the shallow gaseous stratum giving the bright lines are likewise in accord with ARRHENIUS's theory.

W. W. CAMPBELL,
C. D. PERRINE.

March, 1907.

NOTE ON A DISTURBED REGION IN THE CORONA OF AUGUST 30, 1905.[1]

The large-scale photographs of the corona of August 30, 1905, secured by the Crocker expeditions to Spain and Egypt, show an extensive region in the southeast quadrant composed of prominent streamers which appear to radiate from a common point. The space-form of this region seems to be approximately conical. The apex of the cone, projected upon the photographic plate, is some distance within the Sun's limb. The apex no doubt is in or near the photosphere, and the apparent axis of the cone is directed radially out from the Sun's edge. This conical volume is similar to but not so prominent as that recorded in the corona of May 18, 1901.

The chromospheric layer in the region crossed by these projected streamers is not very deep, nor does it show special activity. The streamers probably originate far from the limb; but whether on the nearer or further hemisphere of the Sun is uncertain. The estimated points of intersection of the streamers (produced) were marked on the glass side of the Spanish negatives, Nos. 2 and 7, which were exposed at about 8^s and $3^m\ 16^s$, respectively, after the beginning of totality.

[1] From *Lick Observatory Bulletin*, No. 115.

The positions of these points were measured independently by the writers, as follows:

	Position angle from Moon's center.	Distance from Moon's limb.	Observer.
Negative No. 2	131½°	3′.24	W. W. C.
Negative No. 7	133½	3 .24	W. W. C.
Negative No. 2	132	2 .97	C. D. P.
Negative No. 7	132½	3 .11	C. D. P.

Referring these positions to the center of the Sun we have:—

Co-ordinates of Apex of Disturbed Area.

	Position angle from Sun's center.	Distance from Sun's center.	Observer.
Negative No. 2	134°	12′.78	W. W. C.
Negative No. 7	131½	13 .68	W. W. C.
Negative No. 2	134	12 .51	C. D. P.
Negative No. 7	131	13 .98	C. D. P.

An examination of the photographs of the Sun taken at Mt. Hamilton on this date shows a spot of medium size, surrounded by faculæ, in the southeast quadrant, near the Sun's limb. The following position was determined from the negative exposed at 4^h 49^m G. M. T., August 30th, or 3^h 34^m after the coronal photographs were made in Spain.

Position angle of spot.............	140°
Distance from Sun's center........	12′.67

The series of photographs of the Sun taken at Mt. Hamilton for study in connection with eclipse problems extends from August 23d to September 11, 1905, inclusive. During this interval there was no other spot in the southern hemisphere.

The lack of agreement in position of the apex of the disturbed region and the sun-spot at the time of the eclipse, taken in connection with the low velocities already found for coronal matter, suggests that an eruption (due to volcanic, radiation pressure, or other forces) took place at a considerable time previous to the eclipse. It becomes, therefore, of interest to ascertain the position of this spot group when it was on the opposite side of the Sun at about the same distance from the limb as the apex of the disturbance, and also its similar positions an entire revolution before the eclipse. The position-angles of the spot when at [illegible] from the Sun's eastern limb have been determined as follows:—

1905.	July 28	122°	Farther side of Sun.
	Aug. 3	132½	Nearer side of Sun.
	Aug. 24	129½	Farther side of Sun.
	Aug. 30	140	Nearer side of Sun.

It is a question whether such disturbances of coronal matter have their origin in sun-spots or in the faculæ surrounding the spots. It would be interesting to know the times of greatest activity of the spot group in question, but the history of its development is not known to us. The most probable date of the disturbance was August 3d, when the sun-spot was on the nearer side of the Sun. On that date the spot had the same position as the apex. On August 24th, with the spot on the farther side of the Sun, the position-angles of the spot and apex differed 3°.

The form of structure within the disturbed region may be divided roughly into two classes: long, slightly curved streamers, and flocculent masses. The streamers contain no condensations or other details of structure capable of accurate measurement, as a basis for determining the velocities of the matter composing them. If the forms of the streamers are functions of the velocities within them, as considered by Professor SCHAEBERLE, the speed in question would be as great as several hundred miles per second.

A determination of the velocities of some of the flocculent masses near the limb, on the assumption that August 3d was the date of their ejectment, gives a value of 700 feet per second as the minimum radial speed. The masses farther from the limb would require velocities perhaps five times as great in order to carry them to their positions at the time of the eclipse. These results are in accordance with the conclusions based on velocity determinations during the interval of seventy minutes between the occurrence of the eclipse in Spain and Egypt. This determination showed that the velocity of the flocculent masses could not have been over one mile per second.

April, 1907.

W. W. CAMPBELL.
C. D. PERRINE.

RESULTS OF THE SEARCH FOR AN INTRAMERCURIAL PLANET AT THE TOTAL SOLAR ECLIPSE OF AUGUST 30, 1905.[1]

Owing to the existence of thin clouds during the eclipse of 1901 in Sumatra, the search for an intramercurial planet was

[1] Abstract from *L. O. Bulletin*, No. 115.

not as complete as desired. It was made practically certain that there was no body as bright as the 5th magnitude in the region where such a planet would probably be, if one existed.[1]

The eclipse of August 30, 1905, offered unusual advantages for continuing the search. It was possible to occupy three widely separated stations; the eclipse came at a season of the year when the chances for clear weather were excellent at two of these stations, and the duration was longer than the average.

The value of observations at two or three stations, in case a planet should be found, would be very great, for they would enable some idea of the orbit to be obtained. With an observation at only one epoch, nothing of the orbit could be learned, and subsequent re-observation would be very difficult. In any case, the determination of the orbit of such a body, from the infrequent observations that could be secured at eclipses, would present unusual difficulties.

It was therefore planned that each of the three expeditions, despatched through the generosity of Mr. WM. H. CROCKER, should be equipped with four photographic telescopes designed for efficiency in this problem.

With a few minor exceptions, the plans for securing the necessary photographs at each of the three stations were similar to those of 1901, which are fully detailed in *L. O. Bulletin*, No. 24. The only exceptions of importance were the restriction of the field to be searched, and the taking of the duplicate exposures at different times. The fields covered were $29° \times 9°$ in the Spanish cameras, and $25° \times 8\frac{1}{4}°$ in the Labrador and Egypt cameras, the longer axis being parallel to the Sun's equator, as in 1901. The Sun was in the center of these regions.

The programme was carried out as planned at Alhama, Spain, and at Aswan, Egypt, although at the Spanish station there were thin clouds during all of totality. The four cameras at Cartwright, Labrador, had been made ready by Dr. CURTIS, but unfortunately the sky was densely clouded, and no observations were possible.

A hasty examination of some of the Spanish plates, at the station, revealed so few star images that the work was discontinued until the return of the expedition to Mt. Hamilton.

A careful examination revealed the images of thirty-six stars

[1] *L. O. Bulletin*, Vol. I, 183, 1902.

on the Spanish plates and nineteen stars on the Egypt plates. The fewer stars on the Egypt plates is explained by adverse conditions which overbalanced the effect of the thin clouds at the Spanish station.

All of the objects found were identified as known stars. The average faintest visual magnitude of the stars shown is 8.0. Assuming that the average planetary body would be one magnitude fainter photographically than the faintest stars on the plates, then any planet of 7.0 visual magnitude should have been recorded on our photographs. This conclusion is somewhat more far-reaching than could be drawn from the 1901 eclipse results and tends to confirm the belief that some other explanation must be sought for the peculiarities in the motions of *Mercury*.

The recent investigations of SEELIGER on the effect of the matter concerned in the zodiacal light upon the inner planets seem to show that the observed outstanding perturbations in the motions of *Venus* and *Mars*, as well as those of *Mercury*, can be sufficiently accounted for upon a reasonable assumption of the distribution of such matter about the Sun. Should this explanation be confirmed, the only further need to continue the intramercurial search will be for the purpose of determining whether there are *any* asteroidal bodies in that region. A considerable number of such bodies might exist without their combined mass being sufficient to produce appreciable disturbances in the motions of the planets.

C. D. PERRINE.

NOTE ON COMET *b* 1907 (MELLISH).

A telegram announcing the discovery of a new comet by Mr. MELLISH, at Madison, Wisconsin, was received here on the afternoon of April 15, 1907. Observations were secured by the writer with the 12-inch telescope on the nights of April 15th, 16th, 17th, and 29th, and with the 36-inch on April 30th and May 7th. On the first three nights the comet was visible in the 3-inch finder, though faint on the third night on account of increasing moonlight. It was, however, a difficult object to measure because of its diffuseness and irregularity of outline. Examination with the 36-inch telescope on April 16th showed a broad fan-shaped tail in the south-preceding quadrant that could be traced about 6′ from the coma, which

appeared to be roughly circular and less than 2′ in diameter. There was no well-defined condensation.

By May 7th the comet was too faint to measure with the 12-inch telescope. A rough comparison with the ephemeris in *A. N.* 4172 gives the residuals (O – C) for May 7th, $+ 18^s$ and $+ 1'.5$.

R. G. AITKEN.

May 24, 1907.

VISUAL OBSERVATIONS OF COMET 1905 IV.

A note in No. 113 of these *Publications* (p. 88) calls attention to the reobservation, photographically, on March 21, 1907, of this comet, which was originally discovered by KOPFF in March, 1906. Unfavorable weather conditions prevented my looking for the comet with the 36-inch refractor until the night of April 20, 1907, when it was readily seen. Though it was hardly as bright as a 14th-magnitude star, it was not a very difficult object to measure, because it had a well-defined nucleus of about 15½ or 16th magnitude.

A second observation was secured on May 4, 1907, and a comparison of the two with WEISSE's ephemeris in *A. N.* 4166 shows that the observed motion is slightly more rapid than the predicted.

R. G. AITKEN.

May 24, 1907.

NOTE ON COMET *a* 1907 (GIACOBINI).

From four observations (March 9th, by GIACOBINI, at Nice; March 13th, April 3d, by FATH, at Mt. Hamilton; April 9th, by AITKEN, at Mt. Hamilton) a second orbit of Comet *a* 1907 has been computed under the direction of Professor CRAWFORD. The fourth observation was introduced into the computation by the formation of a fictitious third position based on the two April observations.

The four observations are satisfactorily represented by a parabola. The inclination of the plane of the orbit to that of the ecliptic is 141° 39′; the longitude of the ascending node is 97° 39′; the longitude of perihelion is 54° 21′. The perihelion distance is 2.05 astronomical units, and the time of perihelion passage is March 19, 1907. The elements and an ephemeris extending to the end of May are published in *Lick Observatory Bulletin*, No. 113. The comet is moving away

from both the Sun and the Earth, and it is following the ephemeris very closely.

STURLA EINARSON,
A. ESTELLE GLANCY,
ALICE JOY.

BERKELEY ASTRONOMICAL DEPARTMENT,
May 19, 1907.

NOTE ON COMET *c* 1907 (GIACOBINI).

A preliminary orbit of Comet *c* 1907 has just been completed as this number of the *Publications* is going to press. The three observations used were made June 1st, 3d, and 4th, by GIACOBINI at Nice, HAMMOND at Washington, and AITKEN at Mt. Hamilton, respectively. The elements and an ephemeris are given in *Lick Observatory Bulletin*, No. 116. The observations are represented by a parabola. The inclination of the orbit plane to the ecliptic is 16°; the longitude of the ascending node is 161°. It was nearest to the Sun on May 27th, at which time it was 117,000,000 miles distant. The comet is faint and is receding from both the Earth and the Sun. At present it is east of the sickle in *Leo*. It is traveling toward *β Leonis*, and on June 21st will be about 5° due north of it.

STURLA EINARSON,
ESTELLE GLANCY.

BERKELEY ASTRONOMICAL DEPARTMENT,
June 5, 1907.

PLANS FOR OBSERVING THE TOTAL ECLIPSE OF JANUARY, 1908.

Arrangements have been completed to dispatch an expedition from the Lick Observatory to observe the total solar eclipse of January 3, 1908. The Moon's shadow will cross the central Pacific Ocean from west to east, and pass over only two known islands. One of these is Flint Island, in longitude 151° 48′ W. and latitude 11° 26′ S.,—that is, about 390 miles northwest of the island of Tahiti.

The eclipse will occur at 11:18, local mean time, with the Sun at zenith-distance 15°. The duration given by the American Ephemeris will be $4^m 6^s$.

The generosity of Mr. WILLIAM H. CROCKER has made possible the sending of the expedition.

The expedition will sail from San Francisco on November 22d for Tahiti. The problem of transportation from Tahiti to Flint Island and return was a difficult one, but the interest of the Navy Department of the United States Government was enlisted, and the U. S. gunboat "Annapolis" has been detailed to meet the expedition at Tahiti, transport it to Flint Island,

re-embark the expedition after the eclipse, and return it to Tahiti. The "Annapolis" is stationed regularly at Pago-Pago, island of Tutuila, and will be in personal command of his Excellency, Governor MOORE, of Tutuila, while on eclipse duty.

A later statement will describe the personnel and scientific plans of the expedition.

It seemed to me very important that the scientific programme should include a bolometric survey of the solar corona, similar to that inaugurated by Professor ABBOT at the eclipse of 1900. There is certainly no one more competent to undertake this survey than Mr. ABBOT himself. Accordingly, I brought the subject and the arrangements outlined above to the attention of Secretary Walcott of the Smithsonian Institution and Director ABBOTT of the Astrophysical Observatory of the Institution, and they have been so good as to plan for an expedition to secure the bolometric observations. The two expeditions are essentially independent, scientifically, but are united in traveling and subsistence arrangements.

W. W. CAMPBELL.

CHANGES IN THE LICK OBSERVATORY STAFF.

Mr. JAMES D. MADDRILL, Fellow in the Lick Observatory during the past four years, received the degree of Doctor of Philosophy from the University of California in May, 1907. His thesis relates to a photometric and spectrographic study of a number of well-known variable stars of the δ *Cephei* type. An abstract of the thesis will be found in a later number of these *Publications*. Dr. MADDRILL has been appointed astronomer in charge of the International Latitude Observatory at Ukiah, California, in succession to Dr. S. D. TOWNLEY.

Mr. J. C. DUNCAN, former Fellow in the Lowell Observatory, and at present Instructor in Mechanics and Astronomy in the University of Indiana, has been appointed Fellow in the Lick Observatory for the year 1907-1908.

W. W. CAMPBELL.

APPLICATIONS.

Applications are desired for the position of Assistant in the Lick Observatory, and for the position of Fellow in the Lick Observatory. For particulars, address The Director.

W. W. CAMPBELL.

GENERAL NOTES.

Mutual Occultations and Eclipses of the Satellites of Jupiter in 1908.—At the meeting of the Royal Academy of Sciences of Amsterdam on October 27, 1906, Professor J. A. C. OUDEMANS presented a paper on "The Mutual Occultations and Eclipses of the Satellites of *Jupiter* in 1908." A short account of the paper may be of general interest, as the phenomena can be observed by any one possessing a telescope.

The orbits of the four larger satellites of *Jupiter* lie in approximately the same plane. When the Earth is in or near this plane the satellites would appear to move forward and backward along a straight line, thus occulting one another in passing. In the same way, when the plane of the orbits passes through the Sun, there would be mutual eclipses of the satellites. The orbital plane passes through the Earth and the Sun twice in each revolution of the planet, so that these phenomena occur at intervals of about six years. The plane passes through the Sun on April 25, 1908, and through the Earth on July 8th of the same year, so that near these times the respective observations may be made. Some difficulty may be experienced in making the observations near the latter date as *Jupiter* will be at a low altitude, passing to conjunction with the Sun on August 17th.

Up to the present time but few such occultations have been observed, and there is only a single recorded instance of mutual eclipse. For this reason the observations of next year will have a special interest, and their value will lie in furnishing data to correct the elements of the satellite orbits. If these orbits all lay in exactly the same plane, mutual eclipse would occur at each heliocentric conjunction of two satellites near the time named, and similarly mutual occultation at each geocentric conjunction. As this, however, is not the case, some of the conjunctions will occur without bringing about either eclipse or occultation. In the latter case those using micrometers can make observations of value by measuring the difference in declination at the time of conjunction.

The following list is taken from a table given by Professor OUDEMANS, and contains the occultations and eclipses visible

at the Lick Observatory. This will serve for the Pacific Coast States. In observing it will be well to begin before the computed time and watch the progress of the phenomenon as the times given are for central eclipse or occultation.

Time of Eclipse. 1908.	Pacific S. T.	Eclipsed Satellite.	Eclipsing Satellite.	Direction from *Jupiter.*
April 2	10^h 3^m	I	III	East
3	8 26	IV	I	West
4	8 52	IV	II	East
4	9 21	I	II	East
5	11 56	III	II	West
6	12 12	III	I	East
9	12 52	I	III	East
11	7 42	II	IV	East
11	11 43	I	II	East
11	12 24	I	IV	East
22	7 13	IV	II	East
May 1	9 5	II	III	West
1	10 43	II	I	East
5	9 57	III	II	East
6	8 38	I	II	East
10	8 41	I	II	West
11	7 26	III	II	West
13	11 31	I	II	East
17	8 9	I	II	East

Time of Conjunction. 1908.	Pacific S. T.	Occulted Satellite.	Occulting Satellite.	Direction from *Jupiter.*
May 31	8^h 46^m	I	II	East
June 8	7 57	IV	II	West
9	9 18	III	I	West
29	7 56	I	II	West
July 11	6 57	II	I	West

March 7, 1907. E. A. FATH.

Recent Double-Star Observations.—In Part 3 of Volume X of the *Publications* of the Washburn Observatory, Professor GEORGE C. COMSTOCK publishes the results of his observations of double stars in the years 1897-1906, made with the 15-inch refractor. The measures are arranged in the same form as those previously published by the same observer in Part 1 of Volume X, and constitute with them a homogeneous series.

It is a pleasure to examine this publication, for the observing list has been carefully selected, including only stars in need of measures; the stars have been observed systematically, and the results are arranged in convenient form for the use of investigators, with no superfluous matter. It is to be hoped that his many other investigations will not prevent Professor COMSTOCK from continuing with his double-star observations.

A volume of quite different character is one entitled "Measures d'Etoiles Doubles faites a l'Observatoire de Chevreuse de 1904 a 1906, par MAURICE FARMAN." The exterior of the volume leads one to infer that M. FARMAN was a most industrious observer, for it is a quarto publication of 128 pages. Examination shows, however, that M. FARMAN's own observations occupy only one line for each star, the remaining lines—half a column in many cases—being devoted to a résumé of other observers' results between the years 1875 and 1895. As the observing list is drawn almost exclusively from the lists of STRUVE, OTTO STRUVE, and BURNHAM, of which we possess catalogues giving practically complete histories of each star to the present time, it would seem that the space thus occupied in the present volume could have been used to better advantage by giving the observer's own results in more detail. As it is, he gives only the distance, angle, and date, without any information as to the number of nights the pair was observed, the atmospheric conditions, the hour-angle, or the accordance of the measures. It is stated in the introduction that each position-angle is the mean of five settings, and each distance the mean of ten double-distance measures, and it is perhaps to be inferred that each star was observed on one night only. The measures were made with a refractor of $0^{m}.24$ aperture, and an eye-piece magnifying about 500 diameters. R. G. A.

Eros Comparison-Stars and the Magnitude Equation.—In Number 111 of these *Publications* a brief note was printed calling attention to Dr. FRITZ COHN's investigation of the reference-stars used for the observations of *Eros*. Dr. COHN concluded that the photographic determinations of the positions of these stars at several observatories show a decided magnitude equation. In a later number of the *Astronomische Nachrichten*, Professor HINKS, of Cambridge, England, who has made a very thorough study of the *Eros* comparison-stars,

controverts this conclusion and gives his reasons for thinking that whatever other systematic errors may inhere in the photographic method, these particular observations are free from this special error. A very interesting discussion of the whole question has thus arisen, and a number of articles on the subject may be found in the *Astronomische Nachrichten*, the *Monthly Notices R. A. S.*, and other journals, the outcome of which cannot yet be stated.

It has long been known that practically every meridian observer has a personal equation due to magnitude,—that is, that he observes the transit of bright stars relatively too early as compared with the transit of fainter stars. Careful observers usually determine the amount of this equation by a series of special observations in which the transit of bright stars over half the field is observed at full brightness, and over the other half through a screen placed before the object-glass which reduces the brightness several magnitudes. It has been claimed, and Dr. COHN assumes in his argument, that observations with the Repsold self-registering transit-micrometer are free from this systematic error. The questions at issue can only be decided by careful investigations by expert observers. To the amateur perhaps the most interesting feature of the whole discussion is the minuteness of the quantities involved. It is another illustration of the high standard of precision that modern astronomy sets for its followers.

Probabilities.—If any of the readers of these notes are engaged in teaching the theory of probabilities to classes in algebra or the method of least-squares, they may be interested in the example given on page 155 of this number. The textbooks contain plenty of examples, but they are usually "made-up" ones. The writer has often thought that a few real examples, showing that actual results do come out in practical agreement with those computed by theory, would be very helpful in presenting this subject.

The computations employed in the example just referred to may be used in considering other programmes of work which are dependent upon the weather. For instance, suppose a proposition is made to establish a number of astronomical stations, widely separated along the path of totality, for the purpose of observing changes in the outer envelopes of the Sun

during the progress of a total eclipse of that body. The question naturally arises, What is the probability of the skies being clear at *all* of the stations on eclipse day? In order to give concreteness to the problem, let us suppose that it is equally likely to be clear or cloudy at any station, which is not far from the true state of affairs for most localities, then the probability of obtaining clear sky at any particular station is one half. The probability of obtaining clear skies at any two stations (separated sufficiently so as not to be under the same local weather conditions) is the product of their separate probabilities, or one fourth; of three stations, one eighth; of four stations, one sixteenth; of five stations, one thirty-second. If, then, some problem should be proposed which depends for its solution upon observations to be made at five widely separated stations upon the same day, it is seen that it would be utterly foolish to expend money for this purpose, because there would be only one chance in thirty-two of obtaining the required observations. S. D. T.

Notes from "Science."—Professor JOHN KROM REES, since 1881 professor of geodesy and astronomy and director of the Observatory of Columbia University, died on March 9th, in his fifty-sixth year. Professor REES had been ill for several years and had recently been made Professor Emeritus.

Professor HENRY DAVIS TODD, U. S. N. (retired), died at Annapolis, on March 8th, at the age of sixty-nine years. Professor TODD served through the Civil War with distinction, and became head of the Department of Physics and Chemistry at Annapolis in 1878. From 1886 to 1899 he was assistant on the Nautical Almanac, and was director from 1899 to 1900, when he retired.

The death is announced of Mr. HENRY CHAMBERLAIN RUSSELL, F. R. S., government astronomer of New South Wales since 1870, at the age of seventy-one years.

The New York Assembly on March 5th passed the Young Bill, which provides for the establishment of a nautical museum and observatory in Bronx Park, New York.

Dr. GEORGE E. HALE, director of the Solar Observatory of Mt. Wilson, has been elected one of the alumni members of the corporation of the Massachusetts Institute of Technology.

Mr. C. G. ABBOT, who had been for a number of years Sec-

retary LANGLEY'S principal assistant in the Astrophysical Observatory of the Smithsonian Institution at Washington, and latterly its acting director, has been appointed director of the observatory, and Mr. F. E. FOWLE, Jr., hitherto junior assistant, has been appointed aid.

M. HENRI POINCARÊ has been appointed a member of the council of the Observatory of Physical Astronomy at Meudon, in the room of the late M. MOISSAN.

Funds have been donated by Mr. WILLIAM C. SPROUL, State Senator, of Chester, Pa., for the purchase of one of the largest telescopes on the Atlantic Coast for Swarthmore College. The exact amount of the gift, or the size of the telescope, is not known, but the instrument will be quite as efficient as the Government's telescope at Washington or the University of Virginia's telescope at Charlottesville, which are the two largest instruments in the East. The telescope will be in charge of Dr. JOHN A. MILLER, professor of mathematics and astronomy. Senator SPROUL is a member of the board of managers and has been active in the management of the institution since his graduation, in 1891.

Dr. H. C. VOGEL, of the Astrophysical Observatory at Potsdam, has been awarded the Maximilian order for art and science of the Bavarian government.

Professor DAVID P. TODD, of Amherst College, sailed on the "Panama" on May 11th for Colon, Panama, Callao, Peru, and Iquique, Chile, in charge of the Lowell Astronomical Expedition to the Andes, sent out by Professor PERCIVAL LOWELL, of Boston. Mr. E. C. SLIPHER is photographer, Mr. A. G. ILSE, of Alvan Clark & Sons, the instrument maker, and Mr. R. D. EAGLESFIELD, mechanician. The party will observe the opposition of *Mars* with the 18-inch telescope of Amherst College Observatory, and the annular eclipse of the Sun, July 10th, for Professor NEWCOMB.

Abstracts of Papers.—Two recent numbers of *Science,* April 12th and 17th, contain accounts of the meeting of the Astronomical and Astrophysical Society of America, held in New York during the last convocation week in connection with the annual meeting of the American Association for the Advancement of Science. Thirty-one papers were presented before the society and four papers upon astronomical subjects before

Section A of the Association. If we may judge from the titles, many of these papers must have been very interesting. Abstracts of most of them may be found in the numbers of *Science* just referred to.

The American Astronomer.—In a recent issue attention was called to the *Journal* of the Royal Astronomical Society of Canada, a new periodical, published bi-monthly, and similar in scope to our own *Publications*, the *Journal R. A. A.*, and others designed to extend and popularize the study of astronomy. The second number meets the expectations raised by the initial issue, and we trust the *Journal* has entered upon a long life of usefulness.

A publication of a different type is "*The American Astronomer*, an international publication for practical astronomers," published at Marlborough, Mass., of which two numbers have appeared. The object of this journal is to give prompt intelligence of items of interest to astronomers, and it is therefore the aim of the editor, WM. D. MCPHERSON, to publish as often as possible. At present the paper will appear monthly. It is an experiment worth making, and the result will be watched with interest. The subscription price is placed at $2.00 per year.

"*How to Know the Starry Heavens.*"—We are glad to note that this work on popular astronomy by one of the members of our Society, Mr. EDWARD IRVING, has been well received by the public. Very favorable comments have been printed in many journals, like the *Outlook*, that notice scientific books likely to interest the general public. Mr. IRVING'S facts are correct, his style free from technicalities, and his illustrations numerous, well chosen, and well-executed reproductions from excellent modern photographs and drawings.

NEW PUBLICATIONS.

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HAYNES, E. S. The variable RS *Cassiopeiæ*. Columbia: University of Missouri. (Laws Observatory Bulletin, No. 11.) 4to. 14 pp.

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JOST, E. Untersuchungen über die Parallaxen von 29 Fixsternen. Karlsruhe: Veröffentlichungen der Grossherzoglichen Sternwarte zu Heidelberg. (Astronomisches Institut.) Band IV. 1906. 4to. 171 pp. Paper.

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SEARES, F. H. Announcement of preliminary results for variable stars. Columbia: University of Missouri. (Laws Observatory Bulletin, No. 10.) 4to. 22 pp.

SMITH, C. MICHIE. Widened lines in sun-spot spectra. Kodaikanal Observatory: Bulletin No. VIII. 4to. 20 pp. Paper.

STEIN, J. W. J. A. Beobachtungen zur Bestimmung der Breitenvariation in Leiden. Haag: Annalen der Sternwarte in Leiden, Neunter Band, Heft I. 1906. 4to. 237 pp. Paper.

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Report of the British Association for the Advancement of Science, 1906, York. London: John Murray. 1907. 8vo. cxxiv + 831 + 89 pp. Cloth.

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PUBLICATIONS

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OUR DEBT TO ASTRONOMY.

By Russell Tracy Crawford.

Astronomers are so often asked questions such as "What is astronomy good for?" "Why waste your time and energy upon anything so immaterial and unpractical as astronomy?" "What good does it do to know where a comet is going?" etc., that it seems opportune and fitting to answer such questions quite thoroughly. For this reason the subject "Our Debt to Astronomy" has been chosen for this address. These questions and many others of a similar nature show how little thought is given by the general public to such matters, and how carried away they are with the intensely practical ideas of this rapidly advancing age, which seems to have emblazoned upon its banner not "Excelsior," but a glaring monogram of the United States with the curve at the bottom of the U eliminated from the picture. Among other things I hope to convince the followers of this banner of the almighty dollar that astronomy is one of its most potent aids and should therefore be one of its pets, worthy of its support.

Upon this subject Professor Young writes as follows in the introduction to his "General Astronomy":—

"At present the end and object of astronomical study is chiefly knowledge pure and simple; so far as now appears, its development has less direct bearing upon material interests of mankind than that of any other of the natural sciences. It is not likely that great inventions and new arts will grow out of its laws and principles, such as are continually arising from physical, chemical, and biological discoveries, though of course it would be rash to say that such outgrowths are impossible. But the student of astronomy must expect his chief profit to be intellectual, in the widening of the range of thought and conception, in the pleasure attending the discovery of simple law working out the most complicated results, in the delight over the beauty and order revealed by the telescope in systems otherwise invisible, in the

recognition of the essential unity of the material universe, and of the kinship between his own mind and the infinite Reason that formed all things and is immanent in them. . . .

"At the same time it should be said at once that, even from the lowest point of view, astronomy is far from a useless science. The art of navigation depends for its very possibility upon astronomical prediction. Take away from mankind their almanacs, sextants, and chronometers, and commerce by sea would practically stop. The science also has important applications in the survey of extended regions of the country, and the establishment of boundaries, to say nothing of the accurate determination of time and the arrangement of the calendar."

It is the intention here to go further than this, and to speak not only of the present, as Professor YOUNG does, but to go back to the beginning of things and to show the principal accounts in "Our Debt to Astronomy."

Let it be known at the outset that for many centuries, from the beginning of terrestrial affairs, the history of the world is practically the history of astronomy. For many centuries, we cannot say just how many, astronomy was the one and only agent to quicken the thoughts of men and to lead them to a comparatively high state of intellectual development. Place ourselves, if we can, in imagination back into the so-called prehistoric times, and it will at once be evident that the most striking phenomenon of nature—viz., the rising of the Sun, Moon, and stars in the east, their daily journeys across the sky, and their setting in the west—would be the first thing to draw thought and set active minds to speculate. Once started, the keen mind would soon find other phenomena of astronomy to work upon, and in this way was built up that foundation for the superstructure of culture and knowledge which we find in the possession of earliest historical man—our first debt to astronomy.

We find that, in the beginning of what we may call authentic history, astronomy was purely a practical science. Theoretical astronomy there was, wild as it may have been, but it was the practical side of astronomy that was most developed and cultivated. It was very necessary in those times, when agriculture was the main industry, to know when to sow the crops, and when to reap them,—in other words, a knowledge of the season was essential to existence itself. And how, indeed, was a knowledge of the seasons to be had, not only then but now, except by a careful study of the wanderings of the Sun from

its southernmost position to its most northern station, and back again, during the course of the interval of time that we call a year? Let us consider, in particular, the case of the Egyptians. Egyptian civilization would have been impossible but for the Nile floods, which appear with great regularity. The rising waters reach the region of Heliopolis and Memphis almost exactly upon the day that the Sun is at the summer solstice. It is very evident, then, that the Egyptians before us were under obligations to the astronomers of their age to inform them of the time when the Sun would be at the summer solstice. It is no wonder, then, that the Egyptians commissioned their astronomer-priests to observe carefully for the helical rising of *Sothis* or, as we now call it, *Sirius,* the dog-star, to give them the necessary datum upon which their year's material prosperity depended. As every advance in early knowledge and civilization was an essential stepping-stone to our present acropolis of culture, we of to-day owe this a second debt to astronomy.

It must ever be borne in mind that our present-day knowledge has not been attained by the spontaneous outburst of genius in a single generation, but has been built up slowly, step by step, from earliest times, each single advance being a necessary precursor of later development. HIPPARCHUS must precede PTOLEMY, and PTOLEMY must precede COPERNICUS. COPERNICUS made the way easier for KEPLER, and KEPLER in turn added the stone upon which NEWTON built, and so on. To every contributor of a stone in our Temple of Knowledge, whether it be in foundation or superstructure, we of to-day owe a debt.

Incidentally, we have a decided personal interest in the theoretical astronomy of the Babylonians, who gave us the week of seven days, with the names taken from the Sun, Moon, and the then-known five planets, *Mercury, Venus, Mars, Jupiter,* and *Saturn.* Had *Uranus* and *Neptune* been known to them, our week would have been nine days long instead of seven, with one day in nine for rest.

To astronomers and their science we owe the evolution of the ideas and conceptions of the size and shape of our globe. The earliest peoples believed the evidence of the senses, and thought that they lived upon a large flat surface. More ad-

vanced ideas were that the Earth was a truncated cone, and then a cylinder, and finally, even so early as the time of PYTHAGORAS, it was shown to be a sphere. As to its size no definite conception was had until comparatively recent times. The determination of its dimensions to-day would be impossible but for the astronomer.

Astronomy has not always advanced, but has had its set-backs, from which, however, it has nobly recovered. This brings me to speak of the retarding influence of ARISTOTLE and PTOLEMY upon the world's knowledge and culture; its overthrow brought about by astronomers, and the wonderful results therefrom—one of the greatest of our debts to astronomy.

In the third century B. C. ARISTARCHUS of Samos and others of less note had asserted that the Earth was in motion—a very advanced idea for the time; but they could not prove it. Then came a backward step, taken by PTOLEMY, who apparently proved that the Earth was not in motion, but was immovable at the center of the universe. This idea held sway for fourteen centuries, until the time of COPERNICUS. Its overthrow came at about the time of the downfall of the influence of ARISTOTLE. These two accomplishments were the most vital forces of the Revival of Learning. It has well been said that ARISTOTLE retarded the progress of the world's knowledge and culture more than any other one man. His dictum was the undisputed law in the realms of knowledge for seventeen centuries. If any one dared to present an idea contrary to ARISTOTLE the sneering question was ever ready, "Do you think you know more than ARISTOTLE?" and the investigator was completely squelched. This absolute servility to the dogma laid down by the great philosopher furnishes one of the most remarkable pictures in history. But sooner or later this had to end, and the end came with GALILEO, the astronomer. I may recount here the beginning of this end. ARISTOTLE had said that a large heavy body would fall from a given height in less time than a small light one. For seventeen centuries it had never occurred to any one to investigate experimentally the truth of this assertion, or else no one had dared to try it. GALILEO, the astronomer, however, was not content to take the word of anybody, even ARISTOTLE, upon a matter which could be proved or disproved so easily as this.

one. Dramatic indeed must have been the scene when the great astronomer mounted to the top of the leaning tower of Pisa and let fall simultaneously a large heavy body and a small light one, and great indeed must have been the astonishment of the populace gathered to witness the experiment when they beheld the two bodies falling side by side and reaching the Earth at practically the same time, demonstrating, as KIPLING puts it, that "heart-breaking power, the perversity of inanimate things." At that instant fell also the influence of ARISTOTLE in the scientific world.

COPERNICUS had just previously shown that the Earth is in motion about the Sun, and when GALILEO clinched this idea, so to speak, by turning his telescope upon *Jupiter* and there beholding the four moons revolving about the central mass, a miniature world, the revolution was complete. It is difficult for us to imagine what a convulsion must have taken place in the minds of men at that time. The Church had taught that the Earth was stationary, and even to think anything else was the greatest heresy, as it was contrary to Holy Writ. In view of this, is it any wonder that we had the Dark Ages? Because of the unswerving adhesion to dogma in those days it is, again, no wonder that the great astronomer, GALILEO, was brought before the Inquisition, tried and convicted of heresy, furnishing one of the most dramatic, almost tragic, incidents in the history of science. But the ideas once started by COPERNICUS and GALILEO soon began to spread and found firm supporters, and the world once more started on the way of progress. We cannot begin to appreciate the effects of such a revolution in the world's thought. At first sight one would say, "What a loss of importance and dignity!" We are no longer the great IT,—the center of the universe about which all else must turn, and to which all else must be subservient. But, on second thought, we would say, and do now say, "What a gain in beauty and grandeur!" We now find ourselves whirling about the great Sun in the infinite sea of ether, gazing into its immeasurable expanse. Can any one estimate the amount of dollars and cents in this debt we owe to astronomy? No; it is above dollars and cents.

Following quickly upon the steps of these two great astronomers we have KEPLER, who gave us his laws of planetary motion, by means of one of which the scientific mind was

freed from the so-called perfect path, the circle, and was introduced to the use of the general conic. His work, in turn, formed the stone upon which Sir ISAAC NEWTON built so well. It would be a long story, indeed, to recount the various debts we owe to this man, our greatest astronomer. For the more practical-minded, however, I will call attention merely to one of his accomplishments. In evolving his universal law of gravitation, and in furtherance of his astronomical investigations, it became necessary for him to invent a new branch of mathematics—namely, Calculus. Is there any one so daring as to estimate the commercial value of calculus? The idea is staggering. It is beyond human power to make the computation. Without this powerful implement, due to astronomy, what could be done in applied mechanics? Where would our sky-scrapers be? How could we build our battleships? Where would our electric-cars be? How could our enormous bridges be built?—and so on, almost *ad infinitum*.

Less than a month ago, while coming in from Oakland on the electric-car, a friend asked me the old question, in rather inelegant English, "What is astronomy good for?" Among other things I said, "I suppose you see no connection between astronomy and this electric-car?" The answer was a ready "*No!*" The connecting-link is this same calculus.

We find, not only in the applied sciences, but also in many of the natural sciences, higher mathematics to be an absolute necessity. And to what are the higher branches of mathematics due? The answer is, "Principally to astronomy." I wish to quote here from Dr. WILLIAM F. WHITE's article on "The Nature of Mathematical Reasoning," in No. 609 of "The Open Court." He says, "Behind the artisan is a chemist, behind the chemist a physicist, behind the physicist a mathematician." There he stops, but I now add, behind the mathematician the astronomer.

Another great debt that we owe to astronomy is one on behalf of our peace of mind. From the beginning up to the present time there have been, and now are, many people filled with superstition concerning the heavenly bodies. Thanks to astronomy, these are becoming fewer and fewer. In ancient times whole nations were thrown into a panic by an eclipse of the Sun; armies on the eve of battle were commanded to halt, with disastrous results, to await the passing of the ill-

omen of an eclipse of the Moon. Comets were supposed to be within our own atmosphere, and to bring pestilence and disease. These phenomena have been shown by astronomers to be ordinary affairs in the celestial mechanism, having no bearing upon our regular existence. Unusual conjunctions of several planets are even now by some thought to have an important bearing upon the affairs of life. Many crafty people to-day make a livelihood by imposing upon the more superstitious and easily-fooled people by casting horoscopes. One of our daily papers thinks so little of the value of its space as to give up a quarter of a column in every issue to the publication of COZETTE's horoscope for the next day.

Within the last few weeks the papers announced that a comet had been discovered by an astronomer on Mt. Ætna, which was coming directly toward us and would soon annihilate the Earth. Immediately after the appearance of this wonderful announcement this observatory had many letters of inquiry concerning it. Some people evidently believed in it, and wanted to know the exact date when the direful catastrophe would occur. Probably there will always be some who will be thus taken in, but, thanks to the teachings of astronomy, we live in practically perfect peace of mind regarding these things. Nations are no longer convulsed by an unexpected eclipse, and astronomers royal are not decapitated for failure to predict them.

A study of the simple elements of astronomy would be very beneficial to artists and writers. They often make serious mistakes through mere ignorance. It is not very uncommon to see an otherwise beautiful painting spoiled completely by a delicate crescent Moon with its horns pointing toward the Sun. A note in No. 383 of the *Observatory* calls attention to the fact that in chapter I of "Jane Eyre," by CHARLOTTE BRONTÉ, occurs this expression: "(The Moon's) newly risen crescent, attesting the hour of eventide," a statement which makes the author appear ridiculous. Many instances of this kind could be cited.

Finally we come back to Professor YOUNG's statement, to consider the present-day, all-absorbing, dollars-and-cents value of astronomy. You have all probably traveled at night, resting more or less comfortably in a berth of a Pullman attached to an express train, which in its course thunders by a freight

train on a siding. You give but little, if any, thought to it, having confidence in the men running the train. These men in turn have confidence in their running because they are running "on time." Think what it means to the railroads of the country, and to the public, to have the trains running "on time." To be able to handle the enormous traffic of to-day correct time is an absolute necessity. Where do the railroads get their correct time? Another account in our debt to astronomy.

Again, when it became necessary to run the boundary-line between Canada and the United States astronomers had to be employed. Our maps cannot be made without a knowledge of practical astronomy. Extended surveys also require a knowledge of practical astronomy.

I will call attention to one more, perhaps the greatest, commercial debt we owe to astronomy: that is, the service it renders to navigation. Were it not for the data furnished by astronomers, commerce by sea would practically stop. The sailing-master on the high seas could not determine his position, nor in what direction to head his ship in order to reach a desired harbor. Think what this means in dollars and cents, and estimate it if you can. For this one service alone the science of astronomy is worth more in dollars and cents to the world in one week than has been expended upon it since the beginning of civilization. Do you think that Great Britain, for instance, would take in exchange an amount equal to its national debt for what astronomy gives her? I answer for you, most emphatically, "No."

Even these commercial values sink into insignificance when we consider again, in general, what astronomy has done for us in giving us the laws upon which mechanics is based; in pushing mathematics to its present state of development, the effect of which ramifies rapidly; in being one of the most powerful factors in bringing us to a better understanding of nature; and in broadening our views and taking us out of the narrow confines of a little plain, immediately surrounding the Ægean Sea, and launching us into the infinite realms of space.

In conclusion, I wish to answer one more question—namely, "While some parts of astronomy may be of value, why exert so much thought and energy upon other parts which are purely abstract and theoretical?" The answer to this is that

we never can tell to what such abstract speculations may lead, and that, in the end, they may give us something exceedingly valuable, either in the commercial world or in the realms of culture and knowledge. A comparison with prospecting may make it clearer. The miner digs day after day with apparently no return. He may continue to do so with no result, no matter how long he labors; but, on the other hand, at any moment he may unearth a rich vein which will more than repay him for his efforts. So it was with KEPLER, when he dug through TYCHO's observations day after day with no result, until finally, after much labor and the use of an enormous store of patience, he struck the vein of planetary motion, and his wonderful laws were brought to light. It was MICHAEL FARADAY who said so well, "There is nothing so prolific in utilities as abstractions."

And now, in closing, I desire to express the hope that you who have heard what I have had to say, and those who may hereafter read what I have said, will ever feel it unnecessary to ask in inelegant English, "What is astronomy good for?"

BERKELEY ASTRONOMICAL DEPARTMENT, July 13, 1907.

THE LOST RINGS OF *SATURN*.

By ARTHUR B. TURNER.

The Moon long since became a dead world, without air or water. The planet upon which we dwell is well advanced in its development; its surface has cooled and hardened, but it still has air and water, the great life-giving elements. We look out upon the planet *Mars* with its surface covered by canals in the struggle of the inhabitants to get water to supply their needs. But beyond *Mars*, at a distance more than nine times our distance from the Sun, there circles a world, resplendent in the making, surrounded by satellites and rings, and taking over twenty-nine years to make its majestic swing around the Sun. This orbit formed the boundary to the solar system down to the discovery of *Uranus*, by HERSCHEL, in 1781. *Saturn* has a diameter a little more than nine times that of the Earth, and makes over two revolutions on its axis in one of our days. The result of such swift rotation is to make

the planet appear perceptibly flattened at the poles viewed in the telescope. A vast envelope of clouds surr the fiery ball, which is light enough to float on water.

SATELLITES AND RINGS.

Ten moons swing around this globe, obedient to its a tion, the last one having been discovered by Professor \ PICKERING, of Harvard. The ninth satellite—*Phœ* remarkable in the fact that it disobeys the ordinary la solar motion by moving backwards around the planet.

But the most remarkable feature of this world—disti from all other celestial bodies—is the wonderful syste rings, first discovered by GALILEO, and which appeared t as bright stars on either side of the disk. He says (discovery: "Looking on *Saturn* within these few days I it solitary without the assistance of its accustomed star in short perfectly round—are perhaps the two smaller consumed like spots on the Sun: have they suddenly va and fled? Or has *Saturn* devoured his children?" A this old pioneer of astronomy died without realizing that he had discovered was one of the greatest anomalies (

solar system. It was left for HUYGHENS, in 1655, to announce their true character.

There are three wide, thin rings surrounding the planet in the plane of its equator, and ranging from eleven thousand to eighteen thousand miles in width and about fifty miles thick. They are inclined to our path around the Sun, so that we see them at various angles as they reflect back to us the Sun's rays. It was thought at one time that they consisted of fluid or solid, but the mathematicians proved that such rings would soon fall to pieces, and that probably they consisted of swarms of particles like meteors, each particle following an independent path around *Saturn,* just as the Moon does around the Earth. By spectroscopic observations of the rings by the late Professor KEELER, it was shown that they must consist of discrete particles.

THE LOST RINGS.

The plane of these rings moves parallel to itself as they accompany the planet around the Sun, so that about every fifteen years this plane will pass through the Sun. The Earth in passing around the Sun will view the rings in varying positions. This year the plane of the rings passes through the Sun, and from April 12th to July 22d we face the unillumined side of the rings—the Sun being north and the Earth south of their plane. To us, then, the rings will appear as a black bar crossing the disk of the planet, with possibly a faint line of light where the rings extend on either side of the ball.

In 1891 the great Lick telescope failed to show any trace of the rings when in a similar position. From July 22d to October 4th the rings reappear as a narrow line of light on the two sides of the planet, as shown in the figure above. From October 4 to January 6, 1908, the Earth will be north of the plane of the rings and the Sun south of this plane, and the above phenomena will be repeated. It was this disappearing of the rings that so puzzled GALILEO.

When the rings are more favorably situated we can see the shadow cast on them by the planet, and also the disk shining through the inner dusky "crepe" ring.

COLLEGE OF THE CITY OF NEW YORK,
DEPARTMENT OF MATHEMATICS AND ASTRONOMY.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1907.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

New Moon....	Sept. 7,	1^h	4^m	P.M.	New Moon....	Oct. 7,	2^h	21^m	A.M.
First Quarter..	" 14,	7	40	P.M.	First Quarter..	" 14,	2	2	A.M.
Full Moon....	" 21,	1	34	P.M.	Full Moon.....	" 21,	1	16	A.M.
Last Quarter..	" 29,	3	37	A.M.	Last Quarter...	" 28,	11	51	P.M.

The autumnal equinox, the time when the Sun crosses the equator from north to south, is September 23d, 9 P.M., Pacific time.

Mercury is a morning star on September 1st, rising about half an hour before sunrise, too near the Sun for naked-eye observation. It is moving toward the Sun, and passes superior conjunction on September 6th, becoming an evening star. It then moves out toward greatest east elongation, which it reaches on October 23d; but as its motion carries it southward relative to the Sun, the conditions for visibility are poor, and it does not remain above the horizon as much as an hour after sunset at any time during the period. While it is still a morning star on September 3d, it is in very close conjunction with *Venus*, passing to the north of that planet 26′, less than the apparent diameter of the Sun, but both bodies are too near the Sun to be seen.

Venus, like *Mercury*, is a morning star on September 1st, too near the Sun to be seen, and passes superior conjunction, becoming an evening star on September 14th. After this date its motion relative to the Sun is eastward, and by the end of October its distance is about 12°; but it is also moving somewhat southward, and on October 31st it sets only a little more than half an hour after sunset, so that it is scarcely possible to make any naked-eye observations during the two months. This is rather a rare occurrence.

Mars is still in fine position for observation, setting about half an hour after midnight on September 1st, and shortly after 11 P.M. on October 31st. It has begun to move rapidly eastward, and during the two months' period moves 33° eastward and 8° northward from a position among the stars of the milk-dipper group in *Sagittarius* to the middle of *Capri-*

corn. On September 2d it is a little more than 1° south of *σ Sagittarii,* the right-hand star in the bottom of the bowl of the dipper, and on September 10th passes less than 1° north of *τ Sagittarii,* the left-hand star in the bottom of the bowl. It is in perihelion on the morning of September 26th. Its distance from the Earth changes from fifty millions of miles on September 1st to sixty-six millions on October 1st, and eighty-five millions at the end of the month. By September 1st its brightness is about forty per cent less than it was at its maximum, in early July, and it begins to fall off rapidly during the two months, so that at the end of October it is only one fifth as bright as it was at opposition, but it will still be bright enough to be conspicuous.

Jupiter is a morning star, rising about 2^h 30^m A.M. on September 1st, at about 1 A.M. on October 1st, and at a little before 11^h 30^m P.M. on October 31st. It is in the constellation *Cancer,* and moves about 9° eastward and 2° southward during the two months. On the morning of September 3d it makes a very close approach to the Moon, and for some places will be occulted.

Saturn is in fine position for observation throughout the months of September and October. On September 1st it rises about an hour after sunset, and comes to opposition on September 17th. On October 1st it does not set until nearly 5 A.M., and on October 31st it sets at about 2^h 30^m A.M. It is in the western part of the constellation *Pisces,* and moves about 4° westward and 2° southward. The phenomena of the rings are still very interesting. On September 1st both the Sun and Earth are below the plane of the rings, and we are therefore looking at the illuminated face. The rings appear very narrow, and continually grow narrower until about October 4th; at this date the Earth passes through the plane and we see the rings edgewise. It will take a good telescope to show anything of the rings in such circumstances. For the remainder of the year after October 4th the Sun and Earth are on opposite sides of the plane, and therefore the side facing us is the dark side. The rings widen out a little until about the end of November, and a fine telescope may show this by the curvature of the thin line of light reflected from the edge.

Uranus is in fair position for observation in the evening sky. On September 1st it sets at about 12^h 30^m A.M., on

October 1st at about 10^h 30^m P.M., and on October 31st at about 8^h 30^m P.M. Its motion among the stars is very small—a little westward until September 18th, and then about 1° eastward by the end of October. It remains in the constellation *Sagittarius*, north of the milk-dipper group, about 3° north of ϕ and σ *Sagittarii*, the stars in the bowl nearest the handle.

Neptune rises shortly after 1 A.M. on September 1st, and shortly after 9 P.M. on October 31st. It is nearly stationary in *Gemini*.

NOTES FROM PACIFIC COAST OBSERVATORIES.

NOTE ON COMET *d* 1907 (DANIEL).

This comet was discovered by DANIEL at Princeton on June 9, 1907. The preliminary elements by CRAWFORD, EINARSON, and Miss GLANCEY, of the Berkeley Astronomical Department, indicate that it will pass perihelion on September 4th at about half the Earth's mean distance from the Sun.

In the early part of July I observed the comet here with the 12-inch telescope, and found it to be of about the seventh magnitude and growing brighter. Photographic observations with the Crocker photographic telescope were begun on July 10th and continued every night until July 21st, after which the late setting of the Moon prevented exposures of sufficient length to be valuable. With the Moon away it was possible to obtain exposures two hours long.

The first photograph showed a tail of five or six degrees' length with two longitudinal dark lanes and several knotty condensations. The second, (July 11th) also showed condensations, but since the date of this photograph the tail has consisted of straight or slightly curved, smooth streamers. No identity could be established between the condensation of the tail of July 10th and those of July 11th, and therefore their velocity of recession from the nucleus could not be determined.

Since the photographs were begun the comet has grown rapidly brighter, and the tail has increased rapidly in length and complexity. On the night of July 20th no less than six streamers diverged from the nucleus, and these subdivided into several branches, extending about 12° from the head.

In photographic observations of comets it has been found that, as a rule, the tail changes completely between consecutive nights, so that it is desirable that negatives be made at intervals of a few hours in order that the velocity of particles within the tail may be determined. With this object in view, a second lens, of 6-inch aperture and 32-inch focal length, was mounted

beside the Willard lens. By this means it is possible to obtain two one-hour exposures each night, together with one two-hour exposure, which will show more of the faint detail. The apparatus was used in this way on the nights of July 19th and 20th. Measures made on the point of forking of the principal tail on the short-exposure plates of July 20th indicate a component of velocity of recession from the head, perpendicular to the line of sight, of about seventy miles per second. This apparent motion of the point of forking may be real, or it may be an illusion due to the closing together of the two branches of the fork, which would cause the point of separation to seem to move outward.

The comet is now of the third magnitude, and is rapidly growing brighter. Since July 17th the tail, as well as the nucleus, has been visible to the eye. An ephemeris computed from CRAWFORD's elements shows that the comet will reach its maximum theoretical brilliancy about August 20th, when it will be about twenty times as bright as on June 15th and about twice as bright as it is now. This calculation is of course based on the assumption that all of its light is reflected sun-light, and the actual brilliancy may much exceed the theoretical. At the time of perihelion the comet will be about an hour and a half west of the Sun in right ascension, and it is hoped to extend the series of photographs much further.

LICK OBSERVATORY, July 24, 1907. J. C. DUNCAN.

SPECTROGRAPHIC OBSERVATIONS OF VENUS FOR SOLAR PARALLAX.

The determination of the solar parallax by spectrographic methods has long been under consideration among astrophysicists, but until very recently it has been thought to be out of the reach of spectrographs now in use. The work of taking a series of spectrograms of stars having small latitude was begun by Sir DAVID GILL at the Cape Observatory, and is now in progress. The accuracy with which this series will determine the solar parallax has not yet been fully ascertained; at least it has not been published. Professor KÜSTNER, in an article reviewed by Dr. J. H. MOORE in Vol. 17, 197, of these *Publications*, gets a p. e. of $\pm 0.22^{km}$ for a single plate of *Arcturus*; using eighteen plates, he obtained the value $8''.844 \pm 0''.017$ for the parallax.

The measures of check-plates of *Venus,* taken with the remounted Mills spectrograph in 1904 and 1905, agreed well enough to warrant the taking of a few plates at each of two successive elongations of the planet, to see what weight a value of the solar parallax would have if determined spectrographically from *Venus* alone, and to find out what increase of power would be necessary to put this method on a par with the most accurate of those now in use.

The elements of the orbits of the Earth and the other planets are well determined, but the dimensions are relative. If at any time we can determine the absolute distance from the Earth to another planet, or measure the velocity of any planet with respect to the Earth the absolute size of the whole system can be readily found. Knowing the size of the orbit of *Venus* relative to that of the Earth, the velocity of light and a few absolute wave-lengths we can determine the solar parallax by spectrographic observations of the planet.

While the velocity of *Venus* with respect to the Earth is not so great as that of the Earth with reference to a star on the ecliptic, and while the large hour angles necessary in taking spectrograms of *Venus* are inconvenient, if not prejudicial, the brightness of the planet and freedom from unknown changes in velocity due to satellites and from small spectral variations such as may be encountered in stars, will more than counterbalance the disadvantages when we come to use a more powerful apparatus, such as we are about to discuss. The spectrographic method in general is relatively unaffected by the things that are troublesome in other methods, the most important of which is refraction, and perhaps least important, on account of its accurate determination, the size of the Earth. This method must assume DOPPLER'S principle.

The measurements of the two series of plates taken at the last two elongations of *Venus* showed greater discrepancies than had been expected, and the mean of the two sets differed by 0.4^{km}, so an investigation of the cause for the difference was undertaken. It came out that sky-plates taken with the instrument in the same adjustment as was used for the later series differed from the computed values by the same amount as did the Venus-plates, leading to the conclusion that slight differences in the closure of the slit, or a dust grain, may affect the velocity of a plate by interfering with the symmetry of the

comparison-lines. The value obtained for the probable error of a single Venus-plate was $\pm 0.23^{km}$, of a single sky-plate $\pm 0.18^{km}$. From this we may infer that an instrument five times as powerful would give a result five times as accurate, or a p. e. of $\pm 0.04^{km}$ for a single plate, that is $\pm 0.006^{km}$ for the mean of fifty plates. This would be about the accuracy of an *Eros* determination of the parallax $\pm 0''.004$. A grating ruled 15,000 lines to the inch would give, in the third order, the same angular dispersion as the Mills at λ 4500; 20,000 lines to the inch, third order, or 15,000 lines, fourth order, would give a third more angular dispersion than the Mills, and the resolving power in either case would be over five times that of the Mills if it were a 6-inch grating. The focal length of the Mills camera would have to be multiplied by 3.5 to give sufficient linear dispersion, but it might not pay to increase the collimator focal length in the same ratio, owing to the limited size of gratings that can be ruled. Supposing that this spectrograph and the horizontal telescope necessary to concentrate the light on the slit effectively utilized twenty per cent as much light as the Mills attached to the Lick 36-inch telescope. Throughout the rest of the optical train, the grating would have to throw eight per cent of the incident light into one of the higher orders on one side—not an entirely unknown occurrence—in order to photograph the spectrum of *Venus* in thirty minutes. The Mills gives a dense negative in two minutes. If at one of the next two elongations of *Venus* which are favorable for northern observations a series of plates of the planet and the sky were taken with such a spectrograph as we have considered, and each Venus-plate measured with reference to a separate sky-plate taken the same day, the accuracy of measurement ought to be five times as great as we get with the Mills, and the probable error of a single plate should be as low as $\pm 0.04^{km}$ or $\pm 0.05^{km}$. While we may never get so accurate a value of the parallax by spectrographic methods as by the direct and indirect methods now in use, there is little doubt that a value could be obtained such that its probable error would be much less than the amount by which the values determined directly and indirectly differ, and the result might help to throw light on the cause of the present difference.

Lick Observatory, University of California. K. Burns.

. SPECTROGRAPHIC STUDY OF THE FOURTH-CLASS VARIABLE STARS *Y* OPHIUCHI AND *T* VULPECULÆ.[1]

Introduction.

On account of the extremely small displacements of spectrum nes, due to the radial velocities of the stars, it is desirable to se spectrographs of as high dispersion as possible. The nount of star-light available is the principal factor in deter- iining the upper limit of the dispersion. At present, deter- iinations of the radial velocities of stars are made most ctensively with three-prism instruments. These can be made › yield velocities reliable within a few tenths of a kilometer. 'he practicable limit of such an instrument, attached to the .rgest existing telescopes, is about the sixth photographic iagnitude, which requires an exposure of approximately two nd a half hours. There is urgent need for a knowledge of the idial velocities of much fainter stars. Data for the solution f important astronomical problems by non-spectroscopic iethods have been obtained from a large number of stars, some f which are as faint as the twelfth visual magnitude, whereas idial velocities have really been limited to the sixth photo- raphic magnitude. The one-prism spectrograph of the Lick)bservatory was employed by Dr. R. H. CURTISS in a study f the variable star *W Sagittarii*,[2] which varies between 5.5 nd 6.5 photographic magnitudes. His work showed that good elocity determinations with the one-prism instrument could e obtained, at least when the exposures were comparatively iort. His average exposure was about thirty minutes. It 'as definitely an object of the present investigation to test ie efficiency of this spectrograph for much fainter stars, re- uiring long exposures. The average exposures for the two ariable stars selected (*T Vulpeculæ* and *Y Ophiuchi*) were 5^m and 180^m, respectively. The latter star, of about the eighth hotographic magnitude at minimum, may be considered the racticable limit for this instrument, attached to the 36-inch efractor. In the case of a star whose light is concentrated in few spectrum-lines or bands, it is of course possible to go

[1] Thesis in partial fulfilment of requirements for the degree of doctor of philos- phy in the University of California. A more complete account is published in *Lick bservatory Bulletin*, No. 118, and in the *Astrophysical Journal*, Vol. XXV, 330, 907.

[2] *L. O. Bulletin*, No. 3, 19, 1904; and *Astrophysical Journal*, Vol. XX, 149, 1904.

several magnitudes lower. For example, the spectrum of *Nova Aquilæ* No. 2 was successfully photographed when the star was of the eleventh visual magnitude.

The dispersion of the one-prism spectrograph is one fifth that of the three-prism Mills spectrograph. The average radial velocity of the brighter stars is about $\pm 20^{km}$ per second. The equivalent displacement with the one-prism instrument, for the $H\gamma$ region, is 0.005^{mm}. A radial velocity of 2^{km} would produce a shift of 0.00002 inch (0.0005^{mm}). If the average radial velocity for the fainter stars is about the same as for the brighter, then these small displacements are the quantities to be measured on the plates taken with the one-prism spectrograph. The results obtained are considered highly satisfactory. In the case of *Y Ophiuchi*, with an average exposure of three hours, the double amplitude of the velocity-curve is only 17^{km}. On the Mills spectrograms the same linear displacements would give a curve of $3\frac{1}{2}^{km}$ double amplitude.

In addition to testing the possibility of extending the usefulness of the one-prism instrument for radial velocity work, it was thought that a contribution might be made toward the discovery of the causes of some of the peculiarities that are observed in short-period variable stars of the *δ Cephei* or *η Aquilæ* type. Some of the more important points to be considered in this connection are: The peculiarities of, and the relation between, the light- and velocity-curves, peculiarities of the spectrum, changes in the character of the spectrum during the period of variability, and the behavior of the individual spectrum-lines.

A Peculiarity of the Spectra.

In the variable stars of the *δ Cephei* type there is a greater richness of photographic radiation relatively to visual radiation at light-maximum than at light-minimum.[1] During the light-period the point of maximum energy on the energy-curve shifts along the spectrum, moving toward the shorter wave-lengths as the star approaches light-maximum, and back again toward the longer wave-lengths as light-minimum is approached. This fact is to a certain extent masked upon the spectrograms by

[1] The observations by WILKENS confirm this point. For five stars he finds the photographic range of brightness to be about one half greater than the visual range. —*Astronomische Nachrichten*, Vol. CLXXII, 305, 1906.

umental and atmospheric causes, but in a long series it can ily be verified.

The Individual Spectrum-Lines.

study was also made of the individual spectrum-lines nds) to determine whether any of them were shifted regu- during the light-period of the variable. For this purpose y-nine lines were selected, and for each line the residuals C)—i. e. the velocity given by the line minus the mean all the lines measured on that plate—were formed and ed from the measures of thirty-four spectrograms of *phiuchi* arranged according to phase in the light-period. same was done for thirty-five spectrograms of *T Vulpec-* No definite trace of a shift of any of the lines was found h is progressive with the phase of the star in its light- od.

The Variable Star Y Ophiuchi.

rty-four spectrograms of this variable were obtained. My ures of the first eight spectrograms showed a variable l velocity, the total range of variation being, however, l.[1] The solution of the orbit by the method of LEHMANN- És gave the following elliptic elements:—

$$U = 17.1207 \text{ (light-period)},$$
$$\mu = 21^\circ.026,$$
$$T = 2.6 \text{ days after light-maximum},$$
$$\omega = 209^\circ.2,$$
$$K = 8.5^{km} \text{ (single amplitude)},$$
$$e = 0.10,$$
$$V = -5.0^{km} \text{ (velocity of system)},$$
$$a \sin i = 1{,}999{,}000^{km}.$$

ere is some indication of the presence of a secondary e, with a period equal to half the light-period and a double itude of 2.5^{km}, superimposed upon the elliptic curve given e. This irregularity is such an extremely small quantity he dispersion employed that we cannot place entire con- ce in its reality. It would be equivalent to obtaining a idary curve of 0.5^{km} double amplitude with the three-prism spectrograph. Attention is called to the fact that the -curve shows a similar irregularity.

[1] *lications A. S. P.*, Vol. XVIII, 66, 1906.

More prominent irregularities in velocity-curves have been observed by CAMPBELL[1] in *ζ Geminorum*, and by R. H. CURTISS in *W Sagittarii* (*l. c.*). The cause of these secondary curves is still an unsettled question. Various explanations have been offered, such as the presence of a third body; the rotation of the brighter component; a resisting medium; or the effects of tidal forces, which must necessarily be large in such close binaries. Dr. ALEXANDER W. ROBERTS has shown[2] that considerable deviations of the principal bodies from the spherical form, in the case where the size of the stars is distinctly comparable to the size of their orbits, would give rise to a secondary period in the velocity-curve equal to half the primary period. This is a very interesting and suggestive explanation, though probably not a complete one. In *W Sagittarii* the secondary period is without doubt half that of the primary, whereas in the case of *ζ Geminorum* a secondary period, equal to one third that of the primary, satisfies the observed curve better than one of half the primary period. In a complete explanation probably a number of factors must be taken into account, and in the different individual cases one or the other of these factors may become the predominant one, and thus produce differences in the period of the secondary or in other peculiarities of this class of variables. In the course of a few years, as studies of several other variables of this and related classes will become available, we may hope to be able to speak more authoritatively in regard to the characteristics that are common to all as well as the points of difference. In individual cases we may be able to pick out the predominant influences that are at work.

The Variable Star T Vulpeculæ.

The variable brightness of *T Vulpeculæ* was discovered by SAWYER in 1885. The binary character of the star was announced by FROST in 1904. Three series of spectrograms, in three successive years, were obtained and each series is satisfied by the same velocity-curve. There is thus no appreciable rotation of the line of apsides nor rapid change of any of the other elements. The solution of the orbit was made by the method of LEHMANN-FILHÉS. After several trials of various

[1] *Astrophysical Journal*, Vol. XIII, 90, 1901.
[2] *Monthly Notices R. A. S.*, Vol. LXVI, 329, 1906.

ellipses with different values of the elements, the velocity-curve computed with the elements given below was found to reproduce the observed velocity-curve well within the error of construction of the latter. A least-square solution was therefore considered entirely unnecessary. The following are the adopted elements:—

$$\begin{aligned} U &= 4^{d}.43578 \text{ (light-period)}, \\ \mu &= 81^{\circ}.1583, \\ T &= 3^{d}.76 \text{ after light-maximum}, \\ \omega &= 111^{\circ}, \\ K &= 17.6^{km} \text{ (single amplitude)}, \\ e &= 0.43, \\ V &= -1.3^{km} \text{ (velocity of system)}, \\ a \sin i &= 969{,}180^{km}. \end{aligned}$$

In neither of these two stars could the variability be due to an eclipse, for in that case maximum and minimum brightness would occur near the points where the velocity equals the velocity of the system.

Perhaps the most important result of this investigation is the conclusive evidence of a much closer relationship between the light- and velocity-curves than has heretofore been believed to

Star.	Period.	Time Interval between Maximum Brightness and Greatest Negative Velocity.	Observer.	Reference.
	Days.	Days.		
ζ Geminorum ..	10.15	+0.2	W. W. CAMPBELL at L. O.	*Astrophysical Journal*, XIII, 90, 1901
η Aquilæ	7.18	+0.2	W. H. WRIGHT at L. O.	*Ibid.*, IX, 59, 1899
δ Cephei	5.37	−0.2 ±	A. BELOPOLSKY at Pulkowa.	*Ibid.*, I, 160, 1895
W Sagittarii ..	7.60	+0.1	R. H. CURTISS at L. O.	*Ibid.*, XXII, 274, 1905
T Vulpeculæ ..	4.44	−0.3	S. ALBRECHT at L. O.	This article
Y Ophiuchi ...	17.12	+1.3 ±	S. ALBRECHT at L. O.	This article
U Aquilæ	7.02	+0.5 ±	S. ALBRECHT at L. O.	Not published
X Sagittarii ...	7.01	+0.3 ±	J. H. MOORE at L. O.	Not published
S Sagittæ	8.38	0. ±	R. H. CURTISS at L. O.	*L. O. Bulletin* 62
SU Cygni	3.85	+0.5 ±	J. D. MADDRILL at L. O.	*Pub. A. S. P.*, XVIII, 252, 1906

exist. If the light is sent out equally in all directions from the variable star, the positions of light- and velocity-maxima and minima should bear no special relation to each other, for the brightness would be independent of the direction from which the star is observed, while the radial velocity at any instant is dependent upon the direction of the observer. For different stars

we should, therefore, expect the two curves to be shifted by different amounts relatively to each other around the period. For some stars greatest positive velocity would come at light-maximum, in others at light-minimum, and in most cases at other points along the light-curve. The table of the ten variables of this class for which both light- and velocity-curves are available shows that light-maximum and most rapid approach always occur together. Likewise, there is a time-correspondence between minimum brightness and greatest velocity of recession. We should therefore also expect that when irregularities[1] exist in both light- and velocity-curves, they will correspond to each other in position and perhaps also in shape. Of the ten stars in the above list only two have thus far shown marked irregularities in both light- and velocity- curves. They are *W Sagittarii*[2] and *Y Ophiuchi;* and for these the irregularities in the two curves correspond very closely.

This establishes the fact that in the variable stars of the *δ Cephei* type the light- and velocity-variations are very intimately connected; that both are due to the same causes; and that, if the velocity-variation is dependent upon the direction of the observer, so also must the observed light-variations be dependent upon the same factor.

At present the best theory for this class of variables seems to be that they are binaries, in which one of the component stars is considerably brighter than the other. The observed velocity-variation follows mainly as a direct consequence of the orbital motion of the brighter component. The light-variation seems to be caused in some way (other than eclipse) by the influence of the darker companion. The very close correspondence between the light- and velocity-curves in regard to period and shape, and the agreement of the times of occurrence of maximum brightness with greatest velocity of approach and minimum brightness with greatest velocity of recession, would indicate that the light-variation is not so much dependent upon the position of the brighter component of the system in its orbit as upon the direction from which the star is observed. This would ascribe less direct influence to the darker com-

[1] All the irregularities observed in the brightness- and velocity-curves of the stars contained in the table fall between light-maximum and light-minimum, except in the case of *ζ Geminorum*.

[2] *Astrophysical Journal*, Vol. XXII, 274, 1905.

panion in the matter of liberating an unusual amount of energy in a certain part of the orbit, most likely a small fraction of the period after periastron passage. Dr. CAMPBELL has called my attention to the fact that the *Algol* variables, which are binaries of even shorter average period than the δ *Cephei* variables, show no evidence of light-variation other than that caused by eclipse, and that the apparent failure of two *Algol* components to disturb each other should make us careful in ascribing the total observed effects in δ *Cephei* variables to the mutual disturbing powers of the components. Most of the eclipse variables have earlier-type spectra (*B*, *A*, and *F*) than the variables of Class IV. It is not impossible that in close binary pairs having the simpler types of spectra (*Algol* variables) the mutual disturbances are less effective in producing brightness-variations than in close pairs having older types of spectra (δ *Cephei* variables).

S. ALBRECHT.

ON THE DISTORTIONS OF PHOTOGRAPHIC FILMS ON GLASS.[1]

Introduction.

In various lines of astronomical research depending upon photographic plates, discrepancies of a considerable magnitude occasionally appeared, which seemed attributable to no definite cause. On the star-photographs taken with the Crossley reflector these occasional discrepancies, which seemed to be more or less accidental, usually amounted to a few tenths of a second of arc, and very rarely to as much as a second of arc, which is equivalent to a linear distance of about 0.001 inch (0.02^{mm}). Even though discrepancies are the exception rather than the rule, and discrepancies of the magnitude referred to above are extremely rare, nevertheless they cause considerable annoyance when extreme accuracy is desired, for the error of measurement need not much exceed 0.001^{mm}. It seems highly desirable definitely to locate, if possible, the cause of the difficulty. In the case of the Crossley star-photographs it seemed for a time as though the cause must be sought for in the large mirror of the telescope. Another alternative was the study of the photographic film itself. Accordingly, in the winter of 1904,

[1] Thesis in partial fulfilment of the requirements for the degree of doctor of philosophy in the University of California. A more complete account is published in *L. O. Bulletin*, No. 118, and in the *Astrophysical Journal*, Vol. XXV, 349, 1907.

at the suggestion of Director CAMPBELL and Dr. PERRINE, the writer undertook an investigation of the distortions of the gelatine film.

The more important features of the plan upon which my work was begun were investigations of the effects of (*a*) the position of the plate during the processes of washing and drying, (*b*) the rate of drying, (*c*) abrupt changes in the rate of drying during the process, (*d*) change in the position of the plate while drying, (*e*) hardener. Emulsions on plate-glass were also tried. JEWELL'S developer was used, and the plates were 3¼ x 4¼ inches (83×108^{mm}) in size, the same as are used with the Crossley reflector.

Summary of Results.

1. For the size of the plates used (3¼ x 4¼ inches) it was found to be entirely indifferent whether the plate be vertical or horizontal during development, fixing, washing, and drying.

2. Within the range of the observations, hardener, the rate of drying, and changes in the rate of drying and in the position of the plate during the process of drying introduced no general distortions of the gelatine film.

3. Local distortions were found on artificial-star plates and on spectrograms. These distortions were confined in each case to an area equal to a small fraction of a square millimeter. The largest lateral displacement found at any point in the distorted area was 0.02^{mm}, while the great majority were less than one fourth of this amount. Some of these displacements are several times as large as the errors of measurement, and their possible effects must be taken into account where great accuracy is desired.

4. These distortions seem to be principally of two different kinds: one was due to an actual movement of a minute portion of the film, the other was an apparent shift of the image due to the peculiar arrangement of the silver grains or to local differences in the sensitiveness of the film.

5. The results obtained from one plate-glass plate showed no advantages of the plate-glass over the ordinary commercial plates in the matter of distortions of the film.

6. If the results obtained in this investigation for small plates be found to apply with equal force to larger plates, it will follow that the assumption which is the basis for the use of

the reseau is not well founded. The assumptions involved, briefly stated, are as follows: First, general distortions exist; second, they differ in different parts of the plate; third, they may be assumed to be linear within the squares of the reseau (i. e. over a stretch of 5^{mm} or more). The supposed advantages of the reseau over the method of referring all the measures to a common center rest entirely upon the validity of these three assumptions. If the reseau can be dispensed with there will be a saving of the labor involved in making the large number of settings on the reseau-lines and in the reductions of the measurements.

S. ALBRECHT.

LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA,
May, 1907.

NEW DOUBLE-STAR DISCOVERIES.

Since the publication of the list of two hundred and fifty new double stars in *Lick Observatory Bulletin*, No. 109, more than one hundred additional pairs have been discovered with the 36-inch and 12-inch telescopes of this observatory. Included in this number are the following, which seem worthy of special note:—

29 *Hydræ* = β 590. The 36-inch shows that the principal star is a close double. My measures are:—

1907.21	182°.8	0".17	7.2– 7.2	2^n	*A* and *B*.
1907.21	175 .4	10 .79	6.7–12.5	2	*A B* and *C* = β 590.

According to BURNHAM, the principal star has an annual proper motion of 0".068 in 268°.3. It is clear that this is common to both components, for otherwise the close pair would have been detected by BURNHAM when he discovered the faint star. Measures of *C* show no relative change, hence this star, too, belongs to the system.

B. D. + 46°.2054 = Es. 75. The southern star of ESPIN's pair is a neat double. My measures give:—

1907.40	275°.7	0".63	9.7–9.8	3^n	*A* and *B*.
1907.39	35 .6	4 .39	9.2–9.3	2	*A B* and *C* = ESPIN 75.

In *Astronomische Nachrichten*, No. 3784, ESPIN gives the position for 1880 as 12^h $15^m.9$; + 46° 29', and this is copied by BURNHAM in his general catalogue. It should be 15^h $15^m.9$; + 46° 29'.

53 (μ^2) *Boötis*. The 36-inch telescope shows that this naked-eye star is an exceedingly close double. Measures on

two nights give the distance as only 0″.08 in position-angle 237°.0. In the Harvard photometry the magnitude is given as 4.93, and the two components appear to be of equal brightness. Meridian observations show that the star has a small but well-determined proper motion, and it is therefore obvious that the two components form a physical system. It may be added that 52 and 53 *Boötis* form a close pair when viewed without a telescope.

B. D. + 15°.4181. This 6.5-magnitude star is another example of the close pairs detected with the 36-inch telescope. Measures on one night give:—

1907.519	324°.3	0″.16	7.0–7.0

It is certain to prove a binary system, and it is a member of the class to which most of the rapid binary stars belong. According to AUWERS, the meridian observations give it an annual proper motion of 0″.068 in 297°.4.

B. D. + 52°.2963 = β 370. The 36-inch shows two companions which are too faint to be seen with any telescope previously used to measure BURNHAM's pair. My measures are:—

1907.44	326°.5	3″.30	8.0– 9.0	2n	*A* and *B* = β 370.
1907.44	349 .0	2 .20	9.0–14.5	2	*B* and *C*.
1907.44	239 .5	7 .30	9.0–14.5	2	*B* and *D*.

July 22, 1907.

R. G. AITKEN.

GENERAL NOTES.

Astronomy in Canada.—During recent years the claims of astronomy as a subject for study and research have received marked recognition in Canada. The most striking evidence of this is seen in the fine observatory erected by the federal government on the outskirts of the capital, Ottawa. It was begun in 1902, and occupied in April 1905. The building is a handsome and substantial one, constructed of gray sandstone with brown sandstone trimmings, and finished within in polished oak. The equipment is of the highest grade. The chief instrument is a 15-inch equatorial by BRASHEAR and WARNER and SWASEY, and among its accessories are a position-micrometer, a registering wedge-photometer, a solar camera, a stellar camera of 8-inch aperture, and a universal spectroscope by BRASHEAR. A spectrograph for determining radial velocities has been made at the observatory workshop, and performs admirably. In addition, there is a portable Cooke-Taylor equatorial of 4½-inch aperture; a coelostat with 20-inch mirror; a concave-grating spectroscope of 10-foot radius of curvature; a Fuess heliostat; a 3-inch Cooke transit instrument with traveling-wire micrometer eye-piece; a Bosch seismograph; and a 6-inch meridian-circle is being installed.

The observatory is not connected with any educational institution, but is the official home for astronomical work of the Canadian federal government, the director being Dr. W. F. KING, the Chief Astronomer of the Dominion.

At present a geodetic survey of the country is under way, being carried on chiefly by Messrs. KING, BIGGER, and KLOTZ, while there is much activity in astrophysical research, this being in charge of Mr. J. S. PLASKETT.

At the University of Toronto there have been improvements in the teaching of astronomy, and better facilities for practical instruction and research are under consideration. At present the students in engineering are fairly equipped for geodetic work, while the students in arts have the privilege of using the 6-inch Cooke equatorial and the 3-inch transit instrument belonging to the Dominion Meteorological Observatory, besides receiving some instruction in astrophysics. It is intended to

erect a new observatory in the immediate future. The plans are not yet drawn, but as the new Board of Governors, created last year, are desirous of seeing the university rank with the best in America, it is expected that the equipment will be adequate both for ordinary instruction and research.

Another indication of progress is seen in the success of the Royal Astronomical Society of Canada. The society was founded in 1890 (under another name), and all through its life has received enthusiastic support. The headquarters are in Toronto, but during the last year sections of the society were organized in Ottawa and Peterborough, and several more are under way. In this manner it is hoped to excite interest in the subject in various localities. For some years the Ontario government has given an annual grant, which allowed the issuance of an annual volume of *Transactions*; but a year ago the federal government also gave a grant, and by its assistance a *Handbook* for observers was published, and a bi-monthly *Journal* was also inaugurated. It is hoped to secure further support and make the *Journal* a monthly publication, and it is the aim of those in charge of it to make it a credit to Canadian science. The membership of the society is about four hundred.

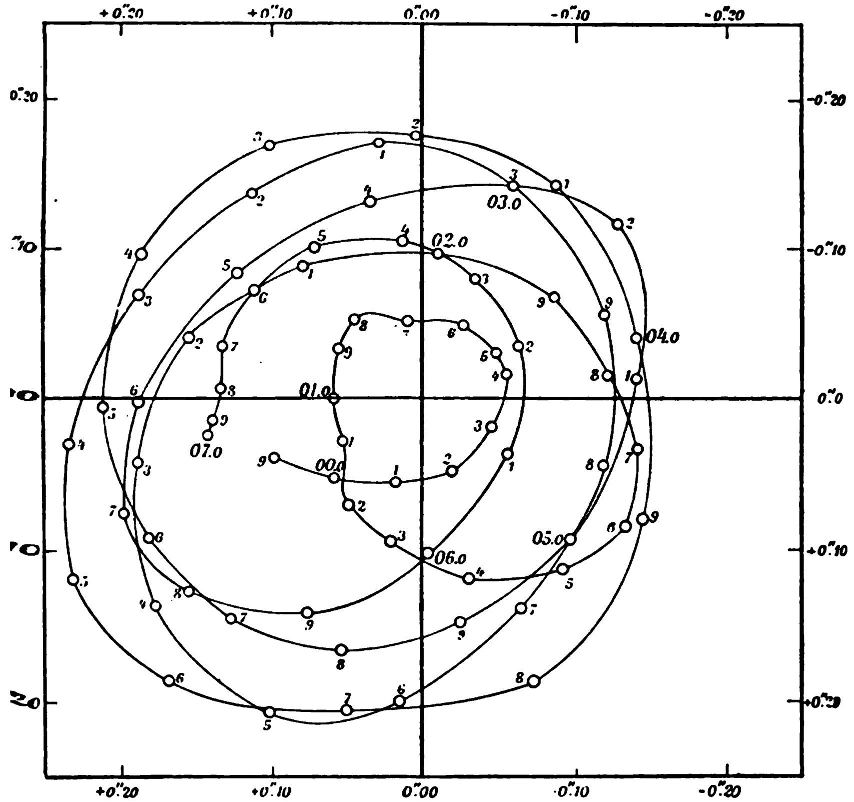
C. A. CHANT.

Variation of Latitude.—From the annual report of the Central Bureau of the International Geodetic Association it appears that the number of latitude determinations made at the various stations established for the purpose of determining the variation of latitude gives a total for 1906 of 12,153, distributed as indicated in the first column of the tabulation given below. The total number of observations made from the time the stations were established, fall of 1899, to the beginning of 1907 is 87,264, distributed as indicated in the second column of the table.

	1906.	Total.
At Mizusawa	1,685	11,718
Tschardjui	1,876	12,920
Carloforte	2,879	22,530
Gaithersburg	1,954	12,741
Cincinnati	1,409	10,974
Ukiah	2,350	16,381

It is learned from the same source that observations were begun during 1906 at the two stations on the southern parallel; on January 6th at Bayswater (West Australia), and on May 5th at Oncativo (Argentine Republic). Good progress was made at both stations, observations being obtained at a rate of over two thousand a year. The observatories at Leiden, Pulkowa, and Tokyo also co-operate with the International Geodetic Association and make continuous observations for latitude. Since the beginning of 1907 observations are being made also by Mr. INNES, at the observatory in Johannesburg, South Africa.

Since the appearance of the last number of these *Publications* provisional results for the latitude work on the northern parallel in 1906 have been published by Professor ALBRECHT, in the *Astronomische Nachrichten,* No. 4,187. The amplitude of



the polar motion continued to decrease during the year, as may be seen by reference to the accompanying illustration, taken from the number of the *Nachrichten* mentioned above, and showing the motion of the Earth's north pole from 1899.9 to 1907.0.

It will be seen from the figure that the position of the pole at the beginning of 1907 is very close to the position first determined when the observations were begun, in the fall of 1899. With reference to the motion of the pole, Professor ALBRECHT says: "Now that we have before us the results of seven years of observations, it becomes evident from them that the assumption of a yearly term and one of fourteen months' period is no longer sufficient to adequately explain the observed path of the pole." S. D. T.

Comet 1894 IV.—In *Bulletin* No. 12 of the Laws Observatory of the University of Missouri, Professor SEARES presents some of the results of his investigation of the orbit of periodic Comet 1894 IV (E. SWIFT).

All the observational data were secured during the comet's traversal of a heliocentric arc of 39° in 1894-5. It would undoubtedly have been seen again in 1901 under ordinary conditions, as account was taken[1] of the perturbations of *Jupiter, Saturn,* Earth, and *Mars* over the seven years. But at its maximum brightness, in 1901, it was fainter than when it passed beyond the power of the 36-inch Lick refractor in January, 1895,—unless some physical change had radically increased its intrinsic brightness. According to the schedule, it has just come to perihelion on another return, and should be rather brighter than at discovery in 1894. Professor SEARES has computed two ephemerides, one assuming the computed perihelion, July 9th, and the other assuming perihelion sixteen days later, throwing the comet about 10° back in its predicted orbit. The uncertainty is due to the meager observational material, and to the large perturbations by *Jupiter* in 1897, when the comet was within half an astronomical unit of the great planet for over six months. Professor SEARES has therefore neglected the comparatively slight perturbations in the interval 1900-1907, during which there was no close approach to any of the major planets.

[1] *Astron. Nach.*, No. 3656.

If the comet is not rediscovered in the next few months there is small chance of its being seen again. If it is found, Professor SEARES' elements of 1894 can be improved, and it should then be possible to demonstrate the identity or non-identity with DE VICO'S comet, 1844 I. The elements of 1844 and 1894 are too uncertain for this purpose.

Professor SEARES does not comment on the converse aspect of the problem. It may be suggested that the *assumption* of identity and computation of the greater disturbances over the fifty years might have yielded elements for 1894 which would have given more accurately the perturbations since 1894. The rediscovery would be simple if the well-grounded assumption is valid. The disintegration of comets seems inevitable, and as the power of comet-seekers is exceeded, and larger apertures become necessary, the limited field greatly lessens the chance of rediscovery. It seems, therefore, that such a computation would have been worth while. It seems, too, that the magnitude of the task need not have been overwhelming. There is ample reason to hope, however, that the comet has not faded beyond the power of comet-seekers, and that the diligence of the comet hunters will be rewarded. Professor SEARES' ephemerides should be ample for their purpose.

JAMES D. MADDRILL.

Notes from Science.—Dr. J. HALM, assistant at the Royal Observatory, Edinburgh, has been appointed first assistant at the Cape Observatory, in succession to Mr. S. S. HOUGH, F. R. S., who was recently promoted to succeed Sir DAVID GILL as H. M. astronomer at the Cape.

Professor GEORGE C. COMSTOCK, director of the Washburn Observatory, University of Wisconsin, was honored with the degree of doctor of laws by the University of Illinois at its commencement on June 12th. A week later the University of Michigan conferred upon him the honorary degree of doctor of science.

Dr. ALEXANDER STEWART HERSCHEL, F. R. S., honorary professor of physics at the Durham College of Science, died on June 18th. Professor HERSCHEL died at the Observatory House, Slough, Buckinghamshire, where his father and grandfather made their great discoveries.

The death is announced of Dr. EGON RITTER VON OPPOLZER, associate professor of mathematics and astronomy at the University of Innsbruck.

The University of Manchester has conferred the doctorate of science on Dr. GEORGE E. HALE, director of the Solar Observatory of the Carnegie Institution.

Solar Observations in India.—A meeting of the Royal Society was held in Edinburgh yesterday—Professor A. CRUM BROWN, vice-president, in the chair. An address, dealing with the work at the solar observatory, Kodaikanal, South India, was given by Professor C. MICHIE SMITH, director of the Kodaikanal and Madras observatories. The observatory is situated on the Palani Hills, in the south of the Madras presidency, at a height of 7,700 feet above sea-level. Long ago it was recognized that India offered many advantages for work on the Sun, but it is only within recent years, after careful inquiries, that Kodaikanal has been selected as the site of the observatory. The hill chosen is an almost ideal site, standing in the midst of a large area of rolling downs, naturally grass-covered but recently planted with eucalyptus. The foundation-stone of the observatory was laid by Lord WENLOCK, governor of Madras, in October, 1895, but, owing to various causes, little was done to the building for nearly three years, and not until the beginning of 1899 was the work far enough advanced to enable the lecturer to take up his residence on the spot. The work consists essentially of as complete a study of the solar surface as possible. The Sun is photographed every morning when it is visible; the prominences are observed, both visually and photographically; and sun-spot spectra are studied in detail. The most interesting instrument in the observatory is the spectroheliograph, with which photographs of the Sun in monochromatic light are taken, so that the details of the distribution of the hot and cold gases may be studied all over the Sun's disk. In addition, the fullest meteorological observations are made, and there is a subsidiary base station some seven thousand feet below and about ten miles distant. Earthquakes are recorded with the Milne seismograph, and a magnetic installation under the direction of the Great Trigonometrical Survey of India is also established.—*The Scotsman.*

Royal Observatory, Greenwich.—A member of the Society has kindly sent a clipping from *The Times,* giving an account of the report of the Astronomer Royal presented to the Board of Visitors at the time of their annual visitation. After giving an account of the work accomplished with the transit instrument, the altazimuth and the reflex zenith tube, and describing the work accomplished on the nine-year catalogue, the account proceeds as follows:—

"The 28-inch equatorial has been used mainly for the observation of lose double stars; κ *Pegasi* has been observed on fourteen nights; the eriod of this star is 11.4 years, and it has now been observed through n entire revolution with the 28-inch. Altogether 129 observations have een obtained during this period, the separation never exceeding 0".3. imilarly δ *Equulei* has been observed on eighty-eight nights during its evolution of 5.7 years.

"With the 26-inch refractor thirty-seven photographs of *Neptune* and is satellite were obtained on eighteen nights. The 30-inch reflector as been used for the photography of very faint objects, the most iteresting of these being *Jupiter's* sixth and seventh satellites, which rere photographed on twenty-nine and seven nights respectively. As ery bad weather was experienced last winter at the Lick Observatory, hich devotes itself more particularly to these satellites, the Greenwich laces will be of additional value. Fifty-four minor planets have been hotographed, the most interesting being No. 588 *TG,* whose period is lmost, if not quite, the same as that of *Jupiter,* so that there is conidérable probability that it may exemplify LAGRANGE's famous proposiion, that three bodies, whatever their masses, may move permanently t the angles of an equilateral triangle. This proposition was enunciated nore than a century ago, but no example of it was found till now.

"The approaching return of HALLEY's comet is commencing to enross attention at Greenwich, which is appropriate, as Greenwich Obervatory was one of the first to obtain observations of this comet at its eturn in 1682, and these observations were utilized by Dr. HALLEY, fterwards astronomer-royal, in the famous researches in which he stablished the period of this comet. As long ago as 1864 DE PONTÉOULANT had published details of the return in 1910, from which time o one else has published anything on the matter. As there were trong reasons for suspecting that he had made a notable error in his alue of the eccentricity, Mr. COWELL undertook a rediscussion, and ound that, in fact, PONTÉCOULANT's value was wrong, so that, while e made the comet's distance from the Sun at its next return sixty-four nillions of miles, the true value is only fifty-five millions. There is a light chance that the comet may be photographed at the end of this ear, when its distance will be about eight astronomical units, and an ccurate knowledge of its position will obviously be of great assistance n detecting such a faint object. Should the comet not be visible then t will in all probability be detected a year later, when it will be near

the orbit of *Jupiter*. The exact day of the next passage cannot yet be given; indeed, since all computers have used some approximations to simplify the work, we must be prepared for an error of a few days in any prediction.

"Photographs of the Sun were obtained at Greenwich on 210 days, and these were supplemented by others taken in India and Mauritius, so that only one day in 1906 is without a photograph. A new departure has been made in the method of publishing the solar results, which should be a great convenience to solar physicists. As soon as the series of plates is complete, rough values of their positions and definitive numbers and descriptions of the groups are now published month by month in the *Observatory*, a magazine edited by members of the staff.

"The astronomer-royal again alludes in his report to the danger caused by the electrical generating station. The committee of three appointed to inquire into the question presented a report to Parliament, in which they made several recommendations as to the manner of working the station. 'If all these are strictly carried out it may be hoped that the work of the observatory will not be seriously interfered with, though further experience when the generating station is completed and in full work may modify this view.' It is found that the vibration trouble may be overcome by using a very thin film of mercury in the trough for reflection observations, but it is feared that the vibration of the instrument, which is undoubtedly going on, may impair delicate work, such as the measurement of close double stars. The danger from smoke and heated air is more insidious, for it is not possible to prove it by immediate statistics; it will be shown only by the gradual deterioration of the observations of low north-stars.

REVIEW.

BURNHAM'S GENERAL CATALOGUE OF DOUBLE STARS.[1]

By Eric Doolittle.

For several years all astronomers interested in double-star observation have been anxiously awaiting the appearance of this great work. It has long been known that Mr. Burnham had at enormous labor formed a complete record in manuscript of practically every double-star measure ever made, and that he had kept this continually posted to date by the addition of each new discovery and measure as it was published. His own account of the need he felt for such a work when he first began his long list of discoveries, and of how he proceeded to obtain it, is found in the "Introduction to the General Catalogue of 1290 Burnham Stars." When the last sentence of this account is duly weighed I think it will be admitted that there are indeed few who would have had the courage to undertake so extensive a labor, and still fewer who, having begun it, would have carried it to a successful conclusion.

"The want of a single catalogue of all double stars visible in the northern hemisphere was very manifest soon after the commencement of the observations with the 6-inch refractor. Many pairs were picked up on every good night which it was desirable to identify with as little loss of time as possible. If wanting in Struve, Herschel, and other of the old catalogues, they might still be known pairs, and it was unsafe to assume that they had not been before observed without a careful examination of minor lists, catalogues, and observations of various kinds scattered throughout a large number of volumes issued by observatories and societies, periodicals, handbooks, and monographs printed in the last hundred years. I was therefore compelled, in the interest of my own work, to bring this material together and arrange all the pairs in order of right ascension in a general catalogue. In this way I made a manuscript catalogue of every known double star within 121° of the north pole, giving the details of measures, magnitudes, star-catalogue references, etc. With this at hand, it was but a moment's work at the telescope to identify any known object, and to decide at once whether or not an object thus found was really a new pair. This catalogue subsequently passed into a second manuscript edition. This

[1] A General Catalogue of Double Stars within 121° of the North Pole, by S. W. Burnham. 2 vols. 4to. pp. lxiii + 1086. The Carnegie Institution of Washington.

served the purpose for a good many years, but the time came when the manuscript became too crowded by the interlineation of stars discovered by myself and other observers, and by the addition of a great number of references to measures and observations, and then I undertook the preparation of a third manuscript edition, which was arranged in the proper form for printing, with ample space for new stars and new observations, and giving a brief statement or discussion of the character of each pair of any general interest. This catalogue is substantially bound in twelve volumes. Very few will fully appreciate the enormous amount of hard work which has been necessarily expended in the preparation of such a work. Whether it will ever assume other than the present manuscript form remains to be seen. It should be remarked in this connection that, with the exception of the four years 1888-1892, all of this astronomical work, with the telescope and otherwise, has been done when eight or more hours of at least six days in the week were more or less occupied with other and very different affairs of life."

This manuscript catalogue was the only work of its kind in existence. Since its formation nearly all double-star observers have been indebted to Mr. BURNHAM for his willingness not only to compare their discoveries and measures with it, but even to copy out for them long lists of stars on which measures are needed. It has long been felt by many that in no direction could money be more profitably spent for the advancement of astronomy than in securing the publication of this catalogue. This has now been accomplished; the work appears as Publication No. 5 of the Carnegie Institution of Washington.

The great value of the catalogue lies not so much in its use to the searcher for new pairs—though to him it is almost indispensable—but more especially in its help to the measurer of known pairs. It should wonderfully increase the efficiency of all double-star work in this direction for many years to come. Without it the preparation of an observing-list has been a long and unsatisfactory undertaking. The observer began by forming a preliminary list of perhaps eight hundred or a thousand stars, which on account of their neglect or motion seemed to require remeasurement. The next step was to go over all the scattered measures in the books and journals which were accessible to him and to strike off one after another each pair which proved to have been adequately measured elsewhere. From the preliminary list he was fortunate if three hundred or four hundred stars remained to constitute his final working list, and unless the libraries to which he had access

were unusually complete he could not even be certain that there were not many of these on which his labor of observing was wasted. When it was a question of rejecting or observing isolated pairs met with after his observing-list was made up, and which seemed of interest for any of several reasons, the matter was still more uncertain. It would always be easier to remeasure such pairs than to hunt through all the prior records of observations, but to do this was to risk wasting a part of the limited number of clear hours available for work. Now that the catalogue is published, all of this labor requires but a few hours, and the observer can easily make certain that the stars which he selects are those most urgently in need of measurement.

The catalogue in printed form comprises two quarto volumes of more than one thousand pages, but, in spite of its size, it is a marvel of compactness. The introduction, which might easily have been expanded into a hundred pages or more, is condensed into very slightly more than eight; the index to seven thousand pairs discovered by the more prominent modern observers is reduced by an ingenious scheme of tabulation to but ten pages, and the seven tables giving the classification when possible of the more than thirteen thousand pairs, as to the character of their motion, requires but eight pages more. This difficult principle of securing the utmost conciseness has been followed throughout, yet it does not appear that a single fact of importance has been omitted.

The first volume contains descriptions of the 13,665 double stars which have so far been discovered within 121° of the north pole. Through an appendix even the most recent discoveries of HUSSEY and AITKEN are included, so that every double star whose discovery was published not later than 1906 will be found in this work. The southern limit of —31° which is adopted for the catalogue includes all of the stars which can be well observed at the northern observatories. In Mr. BURNHAM'S opinion it will probably not be until the end of the present century that measures and discoveries of pairs further south will have so accumulated as to make a similar catalogue of the southern heavens desirable.

The vexed question, Which of the pairs recorded by various astronomers as double shall be included in the catalogue? is here solved by retaining all of them. Mr. BURNHAM writes on this subject:—

"The question of drawing some kind of arbitrary line between what might be presumed to be physical systems, and those which it was practically certain could not belong to that class, was considered at an early day in the preparation of this work. It was soon apparent, from a practical application of the principles which were supposed to govern a judicious separation of the material into these two classes, that it could not be successfully done. A too liberal application of the rule would reject a comparatively small number and so accomplish but little in reducing the size of the catalogue; while, on the other hand, the rigid enforcement would necessarily exclude many stars which are of some interest at least, in consequence of changes already shown from proper motion. Then again, the names of the great astronomers attached to these stars entitle them to a place in the first catalogue of double stars, independent of any consideration of the stars themselves. I have therefore included them all, and as far as possible remeasured the large number of neglected pairs of the old observers for this work."

It seems to us that this is a most fortunate decision. It is to be noticed that, with very few exceptions, it is only the bright or very close doubles which have thus far been observed, and that the orbits of such pairs only are known to us. How many faint and comparatively wide pairs there are which are true binaries we cannot conjecture. There is at least one such example (KRUEGER 60), of which the components are of the 9.0 and 12.0 magnitude and 3".5 apart, whose period will almost certainly not exceed two hundred years. If two thousand or three thousand such pairs are catalogued and a considerable number of these afterward found to be binary, this will go far toward solving the general question of the comparative masses and distances of the faint and bright stars.

Mr. BURNHAM finds that 585 pairs have a common proper motion. Many of these are faint and widely separated, and yet it is very probable that they are physically connected, the periods being reckoned in thousands of years. Perhaps the two best-known examples are μ^1 *Herculis* and 40 *Eridani*, the former being separated by 30" and the latter by 80". That these great distances could have been attained through tidal action seems hardly possible; we cannot even conjecture what the form of their relative paths is likely to be, but to secure and record at least one good measure on every such pair is a debt which the astronomers of to-day owe to posterity. Perhaps the most liberal scheme for the exclusion of double stars is that employed by INNES in his Reference Catalogue of Southern Double Stars. Yet, were this rigorously applied, not only would the distant companions of μ *Herculis*

and 40 *Eridani* be rejected as of no interest, but these two attendants, each of which is a faint binary of comparatively short period, would both be excluded also.

The first volume contains the position of each star reduced to 1880.0, and the date, position-angle, distance, and magnitudes at the time of the first measure. For fully ninety per cent the identification is given; many of those in which this is omitted are too faint to be found in any of the catalogues.

The second volume gives a sufficient number of selected measures to show the character of motion in each pair, and in addition to these the complete references in each case to every measure which has ever been made on it and to all important notes and papers relating to it. The latest values of the proper motions of the principal stars are also included. Mr. BURNHAM is decidedly of the opinion that when many good measures are available the more uncertain ones should be unhesitatingly rejected. He says on this point:—

"For obvious reasons only the best measures by the best observers are selected as a rule, and those made on a single night have been generally rejected, except when there was nothing else in point of time to take their places. It must be clear to every one that the omission of all indifferent and superfluous observations necessarily adds to the value and usefulness of this work. The author has not been handicapped or limited in any way as to space to be used; and in the citation of observations and in the comments relating thereto he has omitted nothing that in his judgment would be worth giving. It goes without saying that a large number of the published measures of double stars should be rejected in any investigation or discussion as to the relative motion of the components. There need be no difficulty or hesitation in deciding as to the proper material to be used. If all the observations—good, bad, and indifferent—are employed in the computation of an orbit, it is certain that the value of the result will be correspondingly impaired, and no method of treating the doubtful material will prevent this."

Beside this enormous labor of compilation there is a condensed but most thorough discussion of each pair in which there has been change. Hundreds of new and carefully constructed diagrams are given in this connection. Certainly no work could be more valuable or more authoritative than this. It is needless to say that Mr. BURNHAM never attempts to get out of the measures more than the material will certainly show. Even in the introduction space is spared to emphasize the inutility of attempting to compute orbits when the measures

are wholly insufficient for this purpose, and in Part II not a line is given up to speculation or to misleading computations of future motion when this must at present be very uncertain. For several of the pairs in which a whole revolution has been completed the period only is stated, and for others for which orbits have been computed it is not even asserted that the motion is orbital at all. As might be expected, Mr. BURNHAM is equally conservative in regard to the presence of dark bodies which have been supposed to disturb the motion of the bright stars. That in *ζ Herculis* is not even mentioned, while the indications of a long suspected third body in F 70 *Ophiuchi* are believed to be equally well explained by the ordinary errors of observation.

When this great mass of material is examined Mr. BURNHAM finds the following general results: There are eighty-eight pairs for which orbits have been computed, of which, however, only thirty-four can be regarded as of any value. There are ninety-four systems which are certainly binary. There are 112 pairs which are probably binary, and thirty-eight pairs in which the two stars have different proper motions, as in the well-known system 61 *Cygni*. There are 585 pairs having common proper motion and 337 in which, from meridian-circle observations, proper motion has been observed in the principal star. Thus of the entire list of 13,665 stars there are but 879 for which a physical connection can at this time be inferred.

No discussion is attempted of the distribution of these stars on the sky, nor is any attempt made to theorize on the construction and extent of the stellar universe. While the discoveries and measures are still both so incomplete, it is the belief that all such generalizations are idle and useless. Mr. BURNHAM strongly emphasizes the fact that what is wanted now for the advancement of double-star astronomy is not theories and speculations, or even extensive computations, but only careful, prolonged, and systematic observations with the telescope. It cannot be doubted that a great impetus will be given to observations in this important branch of astronomy, and that their value will be exceedingly enhanced by the publication of this monumental work.

FLOWER OBSERVATORY, UNIVERSITY OF PENNSYLVANIA.

NEW PUBLICATIONS.

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BLOCK, H. G. Tafeln zur Berechnung der Störungen einer Gruppe kleiner Planeten durch *Saturn*. Stockholm: 1907. 4to. 20 pp. Paper.

BOHLIN, KARL. Der Zweite Sternhaufen im *Hercules*, MESSIER 92. Stockholm. 1906. 4to. 36 pp. Paper.

BURNHAM, S. W. A general catalogue of double stars within 121° of the north pole. Part I, the catalogue; Part II, notes to the catalogue. Chicago: The Carnegie Institution of Washington, 1907. 4to. lv + viii + 1086 pp. Paper.

COMSTOCK, G. C. Observations of double stars. Madison: Publications of the Washburn Observatory, Vol. X, Part 3. 1907. 4to. 106 pp. Paper.

HERZ, N. Stern-Catalog für die Zone von 6° bis 10° südlichen Declination für das Aequinoctium 1890. Abth. I. Abhandlungen der Königlich Preussischen Academie der Wissenschaften, aus dem Jahre 1906. Berlin: Georg Reimer. 1906. 4to. 92 pp. Boards.

JANSSEN, J. Observation de l'éclipse totale de soleil du 30 Aout 1905 a Alcosèbre (ESPAGNE). Annales de l'observatoire d'astronomie physique de Paris. Tome troisieme, premiere partie. Paris: Gauthier Villiers. 1906. 4to. 20 pp. (plates). Paper.

KOPFF, A. Ueber die Nebel der *Nova Persei*. Publikationen der Astrophysikalischen Instituts Königstuhl-Heidelberg. Band II, No. 9. 4to. 27 pp. Paper.

OGBURN, JOHN H. Results of observations with the zenith telescope of the Sayre Astronomical Observatory, from September 11, 1904, to September 1, 1905. South Bethlehem: Lehigh University, Astronomical Papers, Vol. I, Part I. 1907. 4to. 46 pp. Paper.

SCHILLER, KARL. Photographische Helligkeiten und mittlere Oerter von 251 Sternen der Plejaden-Gruppe. Publika-

tionen der Astrophysikalischen Instituts Königstuhl-Heidelberg. Band II, No. 10. 4to. 26 pp. Paper.

SEARES, F. H. Finding ephemerides for Comet 1894 IV (E. SWIFT). Laws Observatory Bulletin, No. 12. Columbia: University of Missouri. 1907. 4to. 4 pp.

TURNER, H. H. Astrographic Catalogue 1900.0. Oxford Section, declination $+24°$ to $+32°$. Vol. I, measures of rectangular co-ordinates and diameters of 65,750 star images on plates with centers in dec. $+31°$. Vol. II, measures of the rectangular co-ordinates and diameters of 66,718 star images on plates with centers in dec. $+30°$. Edinburgh. 1906. 4to. xlvii + 223 and xlii + 232 pp. Paper.

Annales de l'Observatoire Royal de Belgique. Tome IX, Fasc. II, Observations solaires effectuées a Uccle en 1904. Tome IX, Fasc. III, Observations faites a la lunette méridienne de Gambey en 1902, 1903, 1904, et 1905. Bruxelles. 1906. 4to. 108 and 313 pp. Paper.

Publikationen des Astrophysikalischen Observatoriums zu Potsdam. Photographische Himmelskarte-Katalog, Band IV. Potsdam. 1907. 4to. xiv + 519 pp. Boards. 25m.

Solar Physics Committee. Spectroscopic comparison of metals present in certain terrestrial and celestial light sources. (With special reference to vanadium and titanium.) London: Wyman & Sons. 4to. 37 pp. Boards. 3s.

Minutes of the Meeting of the Board of Directors held at the Students' Observatory, Berkeley, on July 13, 1907, at 7:30 P. M.

President Cushing presided. A quorum was present. The minutes of the last meeting were approved.

The following new member was duly elected:—

Mrs. W. B. Cunnane........1327 De la Vina St., Santa Barbara, Cal.

The Treasurer reported that, by order of the Finance Committee, the following bonds had been bought and paid for from the savings bank deposits, viz.:

Alexander Montgomery Library Fund (from Security Savings Bank), Contra Costa Water Company $1,000 Gold Bond No. 1665.. $1,035.00

(Interest January and July; principal due January 1, 1915.)

Wm. Alvord Fund (from Savings and Loan Society), Contra Costa Water Company $1,000 Gold Bond No. 1666...... $1,035.00

(Interest January and July; principal due January 1, 1915.)

Several replies to the circular letter concerning the library were read. Among other contributions to the library were two of cash. It was moved, carried, and ordered that these cash contributions be received, the money thus acquired to be expended for books, to be inscribed as the gift of the donors of said cash contributions.

The following publications were ordered placed upon our exchange list:—

The *American Astronomer.*

The *Journal of the Royal Astronomical Society of Canada.*

Replies, acknowledging with thanks the receipt of the award of the Donohoe comet-medal, from Dr. August Kopff, Rev. Joel H. Metcalf, and Mr. David Ross, were read.

Professor R. G. Aitken, of the Lick Observatory, was elected Secretary at Mt. Hamilton for the unexpired term.

Upon motion it was

Resolved, That the Committee on Publication be authorized to reprint the By-Laws, the Bruce Medal Statutes, and the Donohoe Comet-Medal Statutes.

Adjourned.

Minutes of the Meeting of the Astronomical Society of the Pacific held at the Students' Observatory, Berkeley, on July 13, 1907, at 8 P. M.

President Cushing called the meeting to order, and introduced the lecturer of the evening, Professor R. T. Crawford, of the Berkeley Astronomical Department, who read a paper on "Our Debt to Astronomy."

The Society was very fortunate in having present Professor Simon Newcomb, to whom (in 1897) the first award of its Bruce Medal was made. After the lecture by Professor Crawford, Professor Newcomb was introduced and entertained the Society with a most pleasing informal address. At the close of the meeting the members availed themselves of the privilege of meeting Professor Newcomb.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. CHAS. S. CUSHING .... *President*
Mr. A. H. BABCOCK .... *First Vice-President*
Mr. W. W. CAMPBELL .... *Second Vice-President*
Mr. GEO E. HALE .... *Third Vice-President*
Mr. R. T. CRAWFORD (Students' Observatory, Berkeley) .... *Secretary*
Mr. R. G. AITKEN (Mount Hamilton, Cal.) .... *Secretary*
Mr. F. R. ZIEL .... *Treasurer*

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NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, Students' Observatory, Berkeley.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., Students' Observatory, Berkeley, Cal., who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," Students' Observatory, Berkeley, Cal., in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
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COMMITTEE ON PUBLICATION.

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THE OBSERVATORY OF THE D. O. MILLS EXPEDITION, FROM THE NORTHEAST.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XIX. SAN FRANCISCO, CALIFORNIA, OCTOBER 10, 1907. No. 116.

RECENT CHANGES AT THE OBSERVATORY OF THE D. O. MILLS EXPEDITION.

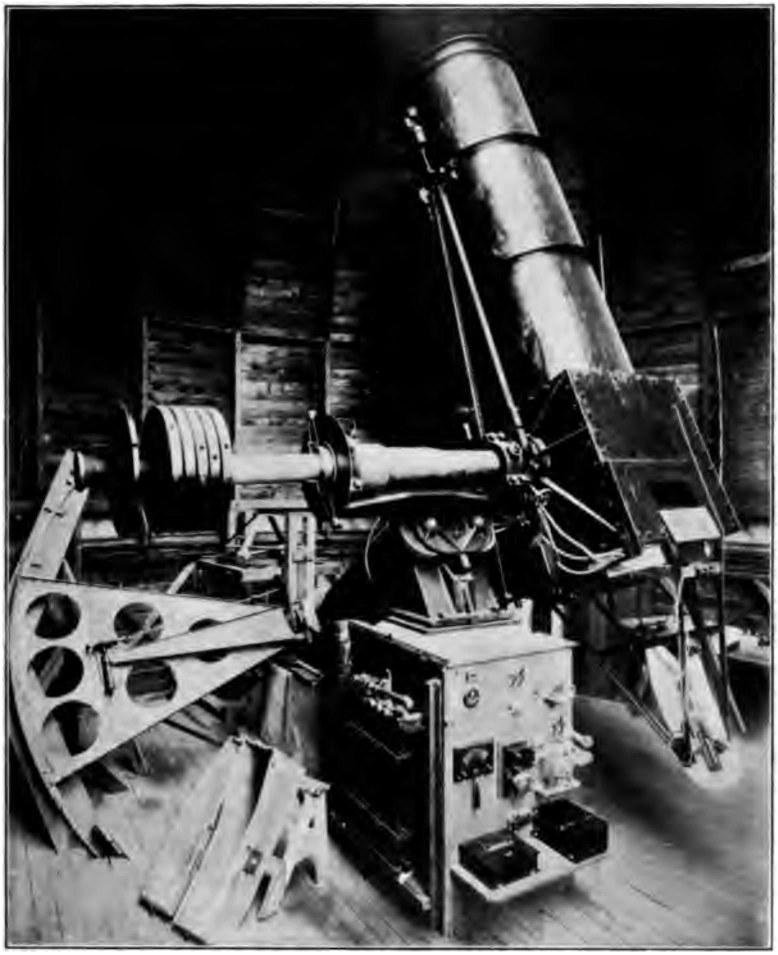
By HEBER D. CURTIS.

When Mr. MILLS provided for a continuation of the work of the D. O. Mills Expedition to the Southern Hemisphere for five years a number of improvements in, and additions to, the equipment were decided upon by Director CAMPBELL, many of which had been suggested as desirable by the experience of Professor W. H. WRIGHT and Dr. H. K. PALMER during the course of their two-year period of work in Chile. It is the purpose of this paper to describe a number of the changes in the equipment which have been made since March, 1906, the date when Professor WRIGHT returned to the United States, and the writer assumed charge of the station. Many of the minor improvements are not of such magnitude in themselves as to warrant extended notice; but if one takes into account the difficulty of accomplishment of all such alterations and additions on a hilltop not too easy of access, in a distant country, and without skilled labor, it can easily be realized that they have cost considerable effort. Mr. GEORGE F. PADDOCK, formerly Fellow at the Leander McCormick Observatory of the University of Virginia, arrived in Santiago on August 2, 1906, and has taken an active part in the installation of all improvements made since that time.

A small building, about fourteen by seventeen feet, was first built, about thirty feet to the south of the observatory dome. It contains a workshop and two small sleeping-rooms for the observers. The observatory is located 860 feet above the city and about one mile distant from the homes of the observers. This daily or nightly climb is a matter of much less bodily strain than would be thought,—after one is well hardened to it,—but there is no change which has contributed more to

the comfort of the observers than the ability to be able to "turn in" immediately after a night's work. In the workshop have been placed a 12-inch Star engine-lathe of the new heavy model made by this company, a grinder-head, a work-bench, and an extensive collection of small tools, as well as a refrigerating machine, to which reference will be made later. The machinery is driven by a one-horsepower electric motor fastened near the ceiling. The electric line from the city to the observatory was in part rebuilt and extended to connect with the circuit of the city's lighting system, and wires were also strung for telephone communication between the observatory and the writer's home at the foot of the hill.

Professor WRIGHT had found the motion of the 37-inch reflector in declination a very difficult one. The axis was of steel, finely ground at the bearing surfaces, and running in babbitt, but such was the weight of the moving parts (about two tons) that much effort was necessary to set the telescope moving in this component. The force required to start the motion averaged fifty to one hundred pounds on the end of a 6.1-foot lever, depending upon the hour-angle of the telescope. After consultation with the makers of the mounting, designs were drawn for roller bearings in each of the declination pillow-blocks, and a ball thrust bearing at the block farthest from the telescope-tube, lack of space preventing its use at the bearing nearest the tube. The new bearings are of the frictionless type manufactured by the Anti-Friction Roller Bearing Company, of Los Angeles. As this company did not have the facilities for making such large bearings as were required in this case, free use of their patent was courteously granted by them to the makers of the mounting, the Fulton Engine Works, of Los Angeles, for the construction of the roller bearings for the Mills reflector. The system for each bearing consists of tool-steel carrying-rolls three fourths of an inch in diameter, with an equal number of alternating smaller rolls, whose only function is to obviate the sliding friction between the larger carrying-rolls. There being nothing but rolling contacts, no lubricant is necessary. Steel rings one fourth of an inch square, fitting into grooves at each end of the rolls, are screwed to the axis, and, with similar holding rings outside the roller group fitting in the same grooves, serve not only to prevent end-motion in the



THE MILLS TELESCOPE, WITH THE THREE-PRISM SPECTROGRAPH.

rolls, but to keep the smaller intermediate rolls in their correct positions. The rolls are eight inches long on the inboard, and five and a half inches on the outboard bearing. For the thrust a strong tool-steel sleeve was made to fit over the declination axis and a tool-steel bearing-ring provided to fit into a shallow recess in the outboard bearing. Between the two steel surfaces there moves freely a bronze ring pierced with seventy-two apertures, each of which contains a half-inch steel ball. The actual work of boring out the heavy bearing-blocks from six and a half to eight inches diameter and recessing the outer block for the thrust-ring was done on the observatory's lathe. The results have proved very satisfactory, the ease of motion being remarkable. It now takes, at a distance of 6.1 feet from the center of motion, but six to nine pounds to start and maintain the motion in declination at all ordinary hour-angles, and only sixteen to nineteen pounds in the extreme case when the telescope is at six hours hour-angle directly over the polar axis. It is now quite easy to move the telescope in declination while looking through the finder with the hand on the corner of the cube only two and a half feet from the center of the declination axis produced. With a centrally hung refractor-tube of the same weight and an available leverage of fifteen to eighteen feet, the very slight effort required to move the tube might even be a disadvantage. The responsiveness of the declination slow motion has likewise greatly improved.

The Cassegrainian system of the 37-inch Mills reflector has from the beginning been subject to progressive focal changes in the first half of the night. These changes were always in the direction of increasing focal length, it being necessary gradually and continuously to increase the focal length of the telescope during the first four or five hours of the night by amounts which reach totals of fifteen to twenty-five millimeters. It was decided to try artificial cooling of the mirror, in the hope that by reducing in advance the mirror temperature to that of the night these progressive focal changes might be greatly reduced or destroyed entirely.

As a preliminary to the testing of the refrigeration the ventilation of the mirror in its cell was bettered. The great mirror has a clear aperture of 36.56 inches, is 5.5 inches thick at the center, and is pierced by a central hole 4.87 inches in

diameter. The cast-iron cell is about one half inch in thickness; at the center of the back is a hole 8.5 inches in diameter, which was formerly generally kept closed with a cast-iron filler disk having a two-inch aperture for the passage of the light to the spectrograph slit. Aside from this aperture, and a few small ones for the adjusting screws of the mirror supports, the only other ventilating opening in the ironwork about the mirror was a small window six inches square cut in one side of the cube just above the mirror. The mirror cover, which had formerly rested nearly in contact with the mirror, was moved fourteen inches up the cube; the cube window was enlarged to six by sixteen inches and a similar window cut on the opposite side of the cube. Six holes, each 5.2 inches in diameter, were cut in the iron back of the cell, and the use of the filler-plate discontinued. The ventilating area at the back of the mirror is thus now about one sixth of the area of the mirror.

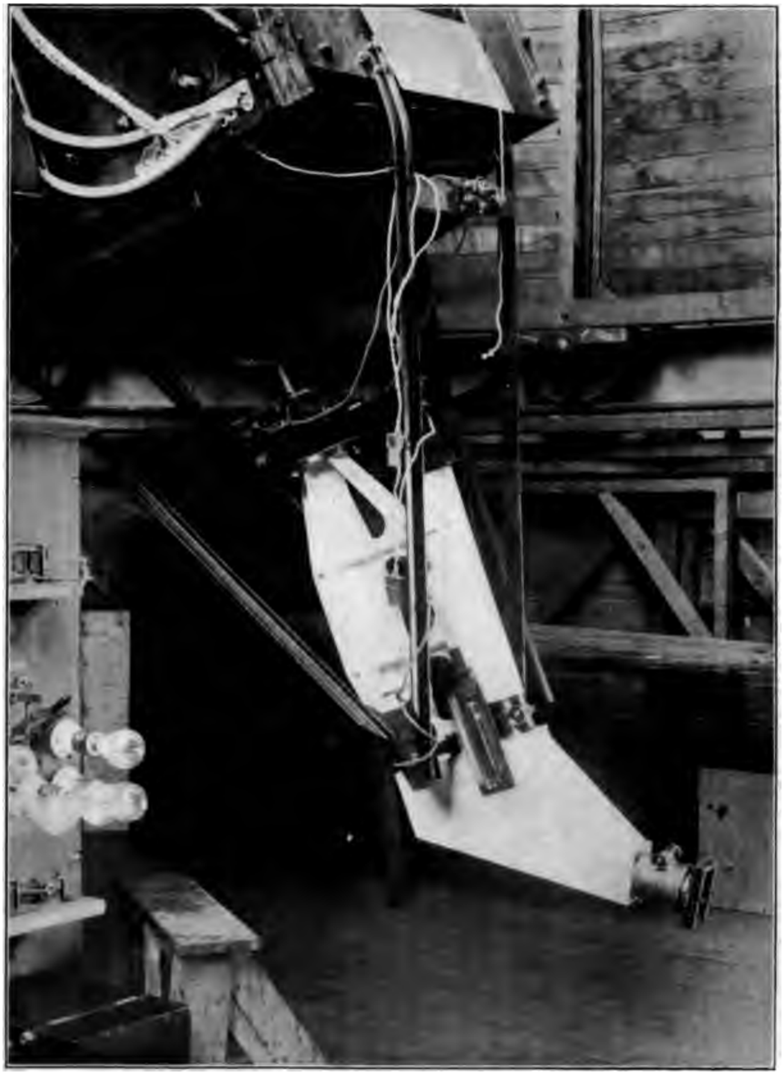
During the past observing season record has been kept of the focal changes, and as a result of the study of these, in connection with the temperature variations, the following general conclusions have been drawn with reference to the behavior of the mirror system without artificial cooling:—

(1) The increased ventilation about the mirror has only slightly reduced the focal range in the first part of the night, the average under normal summer observing conditions being about fourteen millimeters. A position of focal equilibrium is probably reached somewhat earlier, all focal change ceasing as a rule by four hours after sunset.

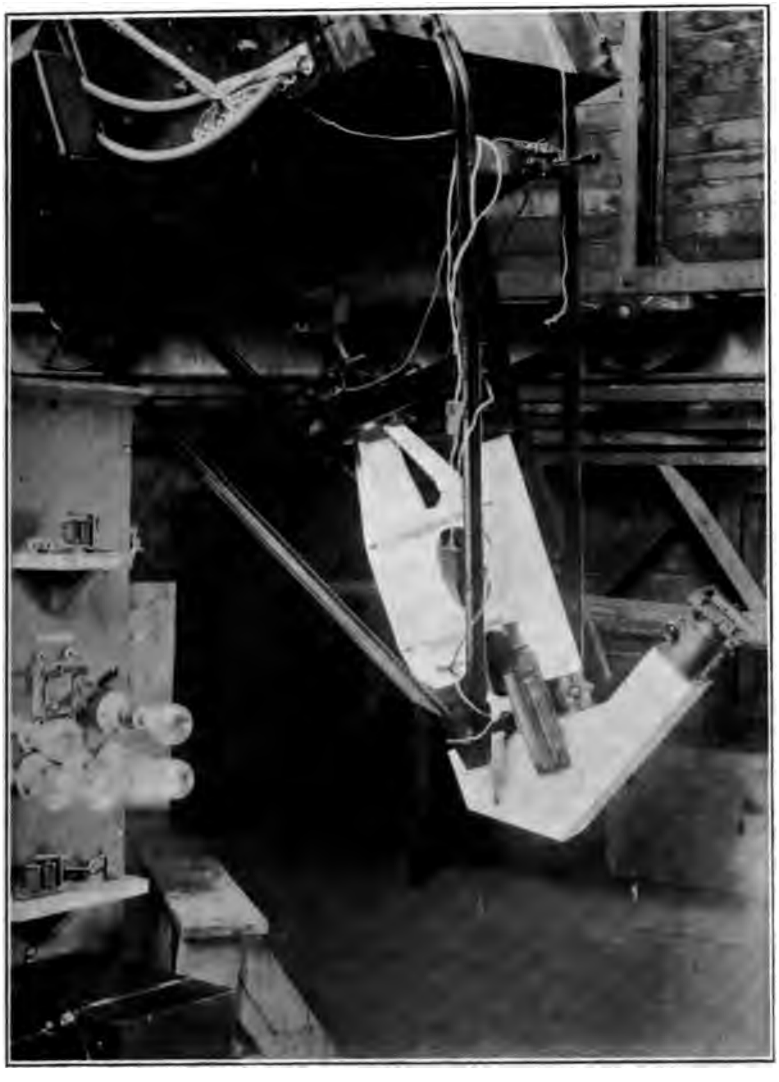
(2) Silvering the back of the mirror, as recommended by Professors Wadsworth and Ritchey, has had no appreciable effect in reducing the focal range. Insulating the sides of the hole in the primary mirror with blanketing has also been without effect.

(3) The focus of the system after equilibrium is reached seems not to vary noticeably for different temperatures.

(4) The focal changes have their origin in the large mirror, and not in the secondary; this has been shown by tests on a number of nights by star-trails on an inclined photographic plate at the focus of the primary. These showed a progressive lengthening of the focus of the main mirror by amounts ranging from 1.2^{mm} to 2.2^{mm}. As a focal change in the



THE ONE-PRISM SPECTROGRAPH.



THE TWO-PRISM SPECTROGRAPH.

primary produces 10.1 times as much change in the focus of the entire system, these results are seen to be in good accord with the ranges secured for the system as a whole. Similar tests on two evenings exposing alternately the inner and outer portions of the primary showed that the outer ring was about 1.2^{mm} shorter focally than the inner zone, a difference which vanished in similar tests made in the morning hours.

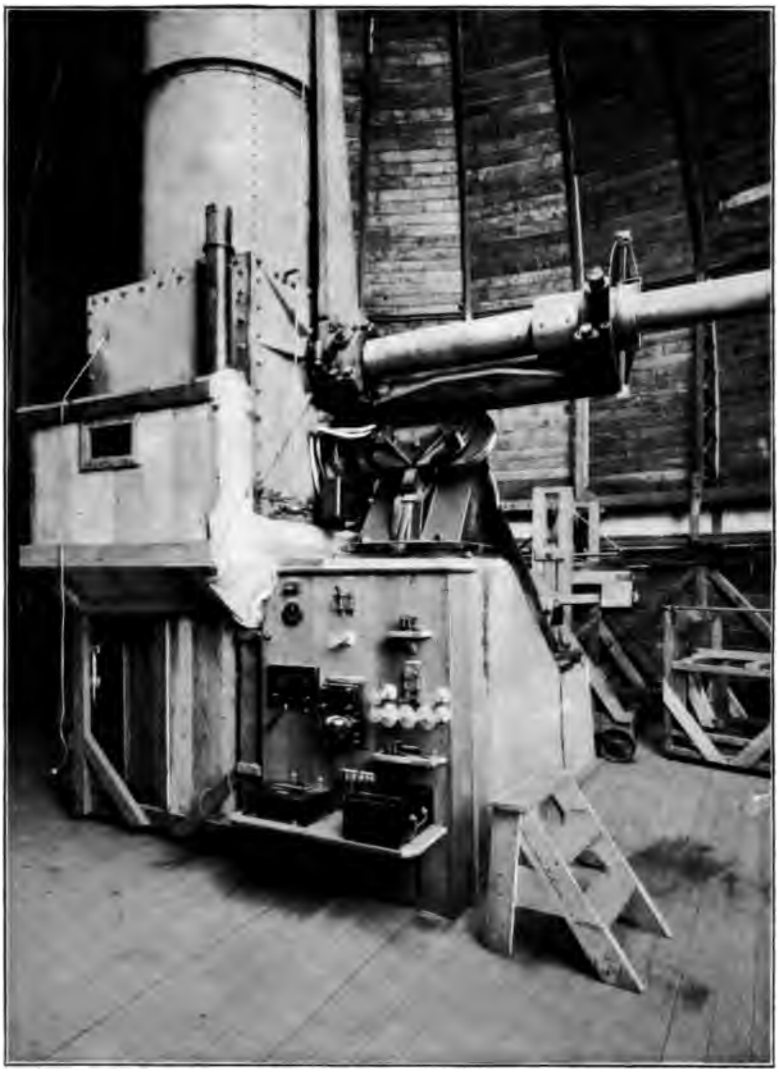
(5) The relation connecting the focal changes of the mirror with the fall in external temperature is apparently a very complex one, many factors entering in. Frequently a drop of 2° C. between the temperatures of afternoon and early evening will cause as great a focal range as a drop of 6° C. In general, the rapidity with which a temperature change takes place seems to be of greater effect than its absolute magnitude.

The system of refrigeration employed is the direct anhydrous ammonia method. The machine is the smallest of the regular commercial sizes of isolated cooling plants manufactured by the Brunswick Refrigerating Company, of Brunswick, N. J. It requires one horsepower to run it and the pump used for water circulation, and is rated by the manufacturers as having a capacity equal to that of the melting of one hundred pounds of ice per day. It is located in the shop forty-eight feet from the telescope pier, to one side of which are attached the cooling coils, three feet by two feet by six inches, of one-inch piping, and well insulated from the pier. The coils are connected with the ammonia machine by a double line of piping of one-fourth-inch bore, insulated with cork and felt. In use a removable wooden case lined with thick felt is rolled into position about the telescope: this case contains about eighty-five cubic feet and insulates from the outside air the spectrograph, mirror, and lower half of the cube. Two electric fans keep the air in the case in constant circulation. The refrigerating machine is entirely automatic in its action, and no difficulty is found in reducing the temperature within the case by 5° or 6° C. in a run of one hour and a half. After some experiments, the following procedure has been found most advantageous. Refrigeration is started about three hours before sunset and the temperature at the mirror reduced about 5° C. The case is removed from the telescope about forty minutes before sunset: at this time the outside temperature is falling rapidly, and the mirror, at least in its outer

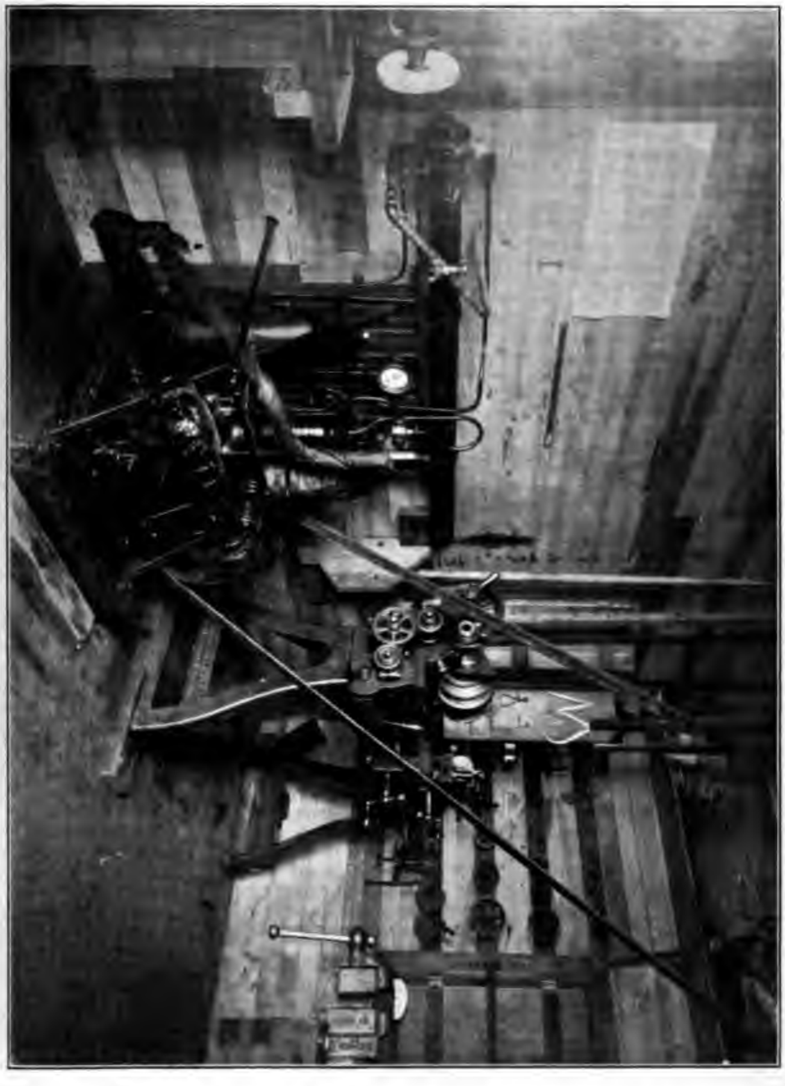
portions, is colder than the air. Equilibrium is reached by sunset, or very shortly after, when focal tests almost invariably show the same value of the focus as that at which it had been left at the time of closing work on the night before. Focal changes are either entirely absent or small, being rarely greater than five millimeters. Sudden changes in the night temperature still produce focal changes of small amount. Fortunately the average temperature gradient during normal summer nights on Cerro San Cristobal is very regular; on quite a proportion of nights when cooling has been used there has been no focal change during the entire night.

The change in the source of electric power rendered necessary the complete rewiring of the observatory, and use was made of this opportunity to arrange all the circuits used in the spectroscopic work in a switchboard on the front of the pier. To this switchboard come, underneath the floor of the dome, a circuit from three primary cells used with the relay for the heating of the spectrograph case; a circuit from four storage-batteries, held in reserve for the spark and used at present only for small lights to illuminate the divided circles; and the 220-volt circuit, used for heating the temperature case, for lights and for the arc comparison. Arc-comparison apparatus has lately been attached to the spectrograph, though the spark is held in readiness for special work; for this latter the condenser and self-induction can be cut in or out by switches. All the electrical circuits, including the high tension for the spark, are carried up over the axes of the telescope to a line of binding-posts near the mirror cell, to which flexible cord and convenient plugs are fitted, doing away with all use of binding-posts in actual work.

A one-prism and a two-prism spectrograph have been added to the equipment. These are arranged to attach to the steel frame of the three-prism instrument by removing the box containing the three-prism train. They use the collimator, slit, comparison apparatus, and supporting truss of the three-prism instrument. The prism-boxes and camera-tubes of the new spectrographs are built up of strong brass plates, the general scheme of construction being that employed in the remounted Mills spectrograph at Lick Observatory. Tests have failed to show any flexure effects. The new camera-lenses are of the Hartmann uncemented type, consisting of



THE REFRIGERATING CASE IN POSITION.



three lenses with intervening air-spaces; the total thickness of glass traversed by the beam at the center of the lenses is 0.92 inch. The focal length of the camera for the two-prism instrument is sixteen inches, that for the one-prism eighteen inches. A special temperature-case fits either of the two new instruments. The heating arrangement is similar to that of the three-prism spectrograph, a mercurial thermostat on the steel body truss serving for all three instruments. It is Director CAMPBELL's intention that radial-velocity determinations in the southern sky shall be carried down to fainter stars with the new instruments, but owing to the long delay in gaining possession of the lenses due to the congestion of business at Valparaiso following the great earthquake, no systematic work has yet been undertaken.

Among minor additions to the equipment may be mentioned a new Toepfer measuring-engine and a Berolina calculating-machine. A photographic attachment has been fitted up to test the performance of the telescope in direct photography of clusters and nebulæ.

The resilvering of the mirror has been expedited by the building of a heavy wooden frame on wheels to withdraw the mirror and cell, and to support the mirror during the process of silvering. A convenient carriage has also been built to remove the spectrograph from the telescope. A card catalogue has been made to keep record of the results of the work; this is on the same plan as that used at Lick Observatory for the results from the northern sky.

Mr. MILLS's generosity in providing this increased equipment for the work of the next five years will add greatly to the comfort of the observers and the ease of manipulation of the instruments, besides materially enlarging the scope and quantity of the work. The present equipment, with spectrographs of one, two, and three prisms, may be considered quite complete for general work in stellar spectroscopy and determinations of stellar velocities, and will render the velocity survey of the stars of the southern heavens much more complete and comprehensive, a result of great moment in improving our knowledge of the Sun's motion through space, and of the structure of our stellar universe.

THE D. O. MILLS EXPEDITION,
Santiago, Chile, June, 1907.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1907.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon....	Nov. 5, $2^h 39^m$ P.M.	First Quarter..	" 12, 9 14 A.M.	Full Moon.....	" 19, 4 4 P.M.

New Moon	Nov. 5	2^h 39^m P.M.
First Quarter	" 12	9 14 A.M.
Full Moon	" 19	4 4 P.M.
Last Quarter	" 27	8 21 P.M.
New Moon	Dec. 5	2^h 22^m A.M.
First Quarter	" 11	6 16 P.M.
Full Moon	" 19	9 55 A.M.
Last Quarter	" 27	3 10 P.M.

The Sun reaches the winter solstice and winter begins December 22d, 4 P.M., Pacific time.

Mercury is an evening star on November 1st, not very far from greatest east elongation, which it passed late in October, but eastern elongations during the last half of the year give a very poor opportunity for seeing the planet as an evening star. The interval between the setting of the Sun and of the planet is less than an hour on November 1st, and diminishes steadily until conjunction in the early morning of November 14th. At this time *Mercury* is in transit across the disk of the Sun. The principal phases of the transit in Pacific time are as follows:—

Ingress, exterior contact,	November	14,	2^h 24^m A.M.
Ingress, interior contact,	"	"	2 26 A.M.
Least distance of centers 12′ 38″	"	"	4 7 A.M.
Egress, interior contact,	"	"	5 47 A.M.
Egress, exterior contact,	"	"	5 50 A.M.

The planet will pass over the north half of the Sun. It will be seen that the transit is practically over at sunrise in the extreme western part of the country, and therefore cannot be seen there, but the latter half of the phenomenon can be seen from the central and eastern parts, the Sun rising after the beginning of transit. The next transit will occur in 1914. Transits of *Mercury* are of little scientific interest.

After November 14th *Mercury* is a morning star, and moves rapidly out toward greatest west elongation, reaching it on the morning of December 1st. It will then rise an hour and three quarters before sunrise, and the interval will not be less than an hour until some days after the middle of the month. *It will* therefore be an easy object to see in the twilight on

early December mornings. By the end of the month the planet will not be far from superior conjunction with the Sun.

Venus is an evening star throughout the month, and shortly after November 1st remains above the horizon long enough after sunset to be easily seen in the evening twilight. On December 1st the interval is a little more than an hour, and by the end of the month it has increased to two hours. Although it is in the part of its orbit farthest from the Earth, it will be a conspicuous object in the evening twilight.

Mars, although it has lost very much of its brilliancy, is still a conspicuous object in the southwestern sky in the evening. During November and December it changes its time of setting only twenty-four minutes, from $11^h\ 11^m$ P.M. to $10^h\ 47^m$ P.M. It moves 38° eastward and 16° northward from the middle of *Capricorn* through *Aquarius* into *Pisces*. On the morning of December 31st it is in conjunction with *Saturn*, passing 1° 50′ north of that planet. During the two months its distance from the Earth increases from 85 to 127 millions of miles, and its brightness at the end of the period is less than one half of that at the beginning, but it is in a region barren of bright stars, and there will be no difficulty in identifying it. *Saturn* is the only bright object near, and its dull yellow color distinguishes it easily from the ruddy color of *Mars*.

Jupiter rises a little before $11^h\ 30^m$ P.M. on November 1st, at $9^h\ 30^m$ P.M. on December 1st, and at about $7^h\ 20^m$ P.M. on December 31st. It is therefore getting around again into good position for evening observation. It moves about 5° eastward and 1° southward up to the end of November, and during December moves a little westward in the constellation *Cancer*.

Saturn sets somewhat earlier, but still remains in good position for evening observation. On November 1st it sets at about $2^h\ 30^m$ A.M., on December 1st at about $12^h\ 30^m$ A.M., and on December 31st at about $10^h\ 30^m$ P.M. It moves westward a little up to November 25th, and then moves eastward, making about 1° by December 31st. It is in the western part of the constellation *Pisces*. Throughout the two months the Sun and the Earth remain on opposite sides of the plane of the rings, and we look toward the dark face, but by the end of December the Earth has nearly reached the plane of the rings once more, and they are nearly edgewise toward us.

During January the Earth will cross the plane and be on the same side as the Sun. This condition of affairs will then continue for fifteen years.

Uranus is in the southwestern sky in the evening, setting a little after 8^h 30^m P.M. on November 1st, at 6^h 45^m P.M. on December 1st, and at 4^h 56^m P.M. on December 31st, only a few minutes after sunset. It will reach conjunction with the Sun early in January, 1908. Its faintness and low altitude will make it a difficult object to see at any time during the two-month period. It is still in *Sagittarius,* and moves about 3° westward. On December 11th it is in conjunction with *Venus,* the latter being 59′ to the south.

Neptune is in *Gemini,* and rises about 9 P.M. on November 1st and at about 5 P.M. on December 31st.

(FIFTY-NINTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. GIACOBINI, of Nice, France, for his discovery of an unexpected comet on March 9, 1907.

Committee of the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
CHAS. BURCKHALTER.

SAN FRANCISCO, September 23, 1907.

(SIXTIETH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Mr. MELLISH, of Madison, Wisconson, for his discovery of an unexpected comet on April 14, 1907.

Committee of the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
CHAS. BURCKHALTER.

SAN FRANCISCO, September 23, 1907.

(SIXTY-FIRST) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. GIACOBINI, of Nice, France, for his discovery of an unexpected comet on June 2, 1907.

Committee of the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
CHAS. BURCKHALTER.

SAN FRANCISCO, September 23, 1907.

(SIXTY-SECOND) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to ZACCHEUS DANIEL, of Princeton, New Jersey, for his discovery of an unexpected comet on June 9, 1907.

Committee of the Comet-Medal:

W. W. CAMPBELL,
C. D. PERRINE,
CHAS. BURCKHALTER.

SAN FRANCISCO, September 23, 1907.

† HERMANN CARL VOGEL. †

It is with the deepest regret that the Astronomical Society of the Pacific has learned of the death, on August 14th, of one of the world's most distinguished astronomers, Geheimer Ober-Reg. Rath Professor Doctor HERMANN CARL VOGEL, Director des Astrophysikalischen Observatorium zu Potsdam, Germany. His death comes as a great blow to astronomical science, as he was one of the most industrious, resourceful, and productive investigators, in spite of the fact that his health had been rapidly failing during recent years. His achievements, well-known to every student in astronomy, will serve as his monument in ages to come. The members of the Society will recall with satisfaction the glowing tribute paid to VOGEL by our past President, Professor TOWNLEY, at the annual meeting in the year 1906, in bestowing upon him the Bruce Medal in behalf of the Society.[1]

Those of us who had the rare fortune of a closer personal acquaintance with him learned to admire his noble character no less than his immortal services to astronomy. VOGEL, first of all, was a man in the true sense of the word, an astrophysicist next. Kind to those who sought his help and advice, charitable in controversy with those who held opposing views in scientific matters, loyal to his staff, generous to his co-workers, faithful and self-sacrificing towards his students, he endeared himself to all who came in contact with him.

It is a source of deep satisfaction to the Astronomical Society of the Pacific that in making its last award of the Bruce Medal to VOGEL it had the opportunity of expressing to the distinguished deceased the high esteem in which his name was held in this country.

A. O. LEUSCHNER.

BERKELEY ASTRONOMICAL DEPARTMENT, Oct. 2, 1907.

[1] Address of the Retiring President of the Society in Awarding the Bruce Medal to Geheimer Ober-Reg. Rath Professor Doctor HERMANN CARL VOGEL. By SIDNEY DEAN TOWNLEY. *Publications A. S. P.*, Vol. XVIII, No. 107.

NOTES FROM PACIFIC COAST OBSERVATORIES.

NOTES ON THE ECLIPSE EXPEDITION TO FLINT ISLAND.

The personnel of the Crocker Eclipse Expedition to Flint Island will consist of Director CAMPBELL, Astronomer PERRINE, Astronomer AITKEN, Assistant ALBRECHT, of the Lick Observatory Staff, and Professor E. P. LEWIS, of the Department of Physics of the University of California. The observers of the Smithsonian Institution Expedition will consist of Director C. G. ABBOT and Mr. ALFRED MOORE, of the University of California. The carpenter, two workmen, cook, and cook's assistant will bring the total number up to twelve, to which the Commander of the U. S. gunboat "Annapolis" desired the party to be limited.

The expedition expects to sail from San Francisco on November 22d, and return on January 25th.

F. K. McCLEAN, Esq., of Tunbridge Wells, England, expects to carry an expedition to Flint Island in a chartered vessel. It will be a pleasure for us to have him and his colleagues as associates on the island.

Meteorological data collected during the month of January, 1907, are very encouraging. The eclipse will occur at about 11:18 A.M. At this hour of the day the sky was clear and fine on about twenty-two days in the month.

MT. HAMILTON, September 23, 1907. W. W. CAMPBELL.

SPECTRA OF THE LIMB AND CENTER OF THE SUN.

In a comparative study of the spectrum of the Sun at the center and near the limb, the following points of difference have been found:—

1. The great majority of the lines that are strengthened in sun-spots are strengthened near the limb.
2. The great majority of the lines that are weakened in spots are weakened near the limb.

3. Most of the lines are slightly widened.
4. The wings of diffuse lines are greatly reduced.
5. In agreement with HALM, most of the lines are shifted toward the red.
6. The amount of the shift varies for different lines of the same element.
7. The lines of the ultra-violet cyanogen fluting are not shifted.

In general, while the results so far obtained point to increased effective pressure near the limb (HALM's explanation) as the probable cause of the line-shifts, judgment is reserved until the completion of laboratory experiments now in progress.

September, 1907. GEORGE E. HALE, and WALTER S. ADAMS.

PRELIMINARY PHOTOGRAPHIC MAP OF THE SUN-SPOT SPECTRUM.

A photographic map, extending from λ 4600 to λ 7200, and consisting of 26 sections of 100 Angströms each, has recently been made by Mr. ELLERMAN from the Mt. Wilson negatives of sun-spot spectra. The original negatives were made with the Littrow-grating spectrograph, of eighteen feet focal length, used with the Snow telescope. Each section of the spot spectrum, after being enlarged on a plate moving in the direction of the lines (by the pendulum process frequently employed for widening stellar spectra), is printed alongside the corresponding region of the normal solar spectrum. An approximate scale of wave-lengths, merely for the identification of lines, and not for the determination of their positions, also appears on each section. It is expected that a more perfect map can be issued later. This is intended to supply the immediate needs of visual observers of spot spectra, and has been placed in the hands of those who are taking part in the work set on foot by the International Union for Co-operation in Solar Research.

GEORGE E. HALE.

September, 1907.

SIX STARS WHOSE RADIAL VELOCITIES VARY.

The following stars have been shown to have variable radial velocities, by photographs taken with the Mills spectrograph at Mt. Hamilton. The approximate range of speed observed

is given in the second column, and the names of the discoverers in the third:—

Star.	Observed Range.		Observed by
o Tauri	— 15 to	— 24^{km}	MOORE.
f Tauri	+ 9	+ 27	MOORE.
η Camelopardalis	+ 22	— 40	MOORE.
A Boötis	— 11	— 40	MOORE.
β Coronæ	— 15	— 33	MOORE.
ξ Cygni	— 19.6	— 24.1	CAMPBELL.

W. W. CAMPBELL,
J. H. MOORE.

TWO STARS WHOSE RADIAL VELOCITIES ARE VARIABLE.

Professor WRIGHT, formerly in charge of the D. O. Mills Expedition to the Southern Hemisphere, has found from their variable velocities that the following stars are spectroscopic binaries:—

x Carinæ, with observed speed lying between + 3.3^{km} and + 17.4^{km} per second.

ι Gruis, with observed speed lying between — 2.3^{km} and — 18.8^{km} per second.

The photographs upon which these discoveries were based were taken at Santiago, Chile, by Messrs. WRIGHT and PALMER in 1904-1905, and by Dr. CURTIS in 1906-1907.

W. W. CAMPBELL.

NOTE ON THE PUBLICATIONS OF THE LICK OBSERVATORY.

In the past years six quarto bound volumes of the *Publications* of the Lick Observatory have been printed and distributed to our correspondents.

Volume VII of the *Publications* will contain articles written by members of the Berkeley Astronomical Department. Parts 1, 2, and 3, relating to a short method of determining orbits, were printed in 1902. Only a few copies were mailed, to those who were especially interested in the subject, and the remainder of the edition was held with the expectation that the succeeding parts of the volume would be published soon and be included in the bound volume. Delay in completing the volume makes it desirable that these parts should be distributed unbound in the near future, following the completion of Parts 4 and 5, now ready to go to press.

Volume VIII of the *Publications,* to contain photographs of nebulæ and star clusters secured by the late Director KEELER and by Dr. PERRINE, has been in preparation for three years past. In common with the experience of others, difficulties have been encountered in securing satisfactory reproductions of the photographs. It has been found necessary to compromise between pictorial effects and strict scientific values, and a fair rate of progress has been made during the past year. It is hoped that means will be found in the near future to make several complete sets of positives on glass of these photographs for deposit with leading scientific societies in various centers of population, in order to make them available to all investigators who desire to study them in detail.

Volume IX of the *Publications* relates to the work of the D. O. Mills Expedition to the Southern Hemisphere. Parts 1, 2, and 3 have just been mailed to our correspondents. They include an account of the organization and history of the expedition by Director CAMPBELL, and a description of the instruments and methods by Acting-Astronomer WILLIAM H. WRIGHT, in charge of the expedition. The spectrograms secured by the expedition will have been measured and reduced in the course of a few months, and it is planned to publish the results for the 145 stars included in the programme as promptly as possible.

Volume X of the *Publications* is more than half through the press. It contains the results of meridian-circle observations by Astronomer R. H. TUCKER. The bound volume will be mailed before the end of the present year.

It is the intention to send out all completed volumes in bound form.

W. W. CAMPBELL.

MT. HAMILTON, September 23, 1907.

A FIREPROOF BUILDING ON MT. HAMILTON.

The construction of the half of a fireproof building is under way at the present time. It is not expected that the second half of the building will be constructed before the summer of 1909. The first half will contain, on the first floor, storage vaults for the valuable and extensive collection of observatory photographs, together with the records and computations for all the observations, visual as well as photographic, and such valuable smaller instruments as are not in daily use. The

second floor will consist of a photographic-enlarging room, fifty feet in length in the clear, provided with graduated steel track to carry the lenses and cameras used in this work. It is expected that these rooms will be available for occupation about January 1st.

W. W. CAMPBELL.

MT. HAMILTON, September 23, 1907.

IMPROVEMENTS TO THE CROSSLEY REFLECTOR.

Mr. F. G. PEASE, recently assistant to Professor G. W. RITCHEY, and now optical expert to The Scientific Shop, Chicago, spent a month on Mt. Hamilton figuring a convex hyperbolic mirror for the Crossley reflector, in order to convert it into the Cassegrain form with an equivalent focal length of seventy-five feet. The corresponding mechanical additions are in course of construction by the Lick Observatory instrument-maker. It is hoped to utilize the Cassegrain form in parallax and spectrographic researches.

MT. HAMILTON, September 23, 1907. W. W. CAMPBELL.

RECENT PROGRESS IN THE CONSTRUCTION WORK OF THE SOLAR OBSERVATORY.

The figuring of the 60-inch mirror was completed by Professor RITCHEY in August, the residual errors not exceeding one tenth of a wave. The final tests were made with the aid of parallel light furnished by a 36-inch plane mirror, also figured in our optical-shop during the year. The various convex and plane mirrors required for the 60-inch reflector when used in the Newtonian and Cassegrainian forms are now being completed.

The mounting for this telescope will soon be finished in our instrument-shop. It is being assembled in Pasadena, and will be thoroughly tested there before being set up on Mt. Wilson.

The Mt. Wilson road was finished in May, and much of the structural steel for the building and dome of the 60-inch reflector has been taken to the summit. The erection of the building is advancing rapidly under the supervision of Mr. GEORGE D. JONES, who also completed the road.

The vertical cœlostat telescope, of twelve inches aperture and sixty feet focal length, has been erected on the mountain, and will be tested in September. The cœlostat and second mirror support by BRASHEAR and the 30-foot Littrow-grating

spectrograph by GAERTNER are in position, and the two plane mirrors, each twelve inches thick, have been figured by Professor RITCHEY.

GEORGE E. HALE.

September, 1907.

PROFESSOR JULIUS'S VISIT TO MT. WILSON.

As the outcome of a plan arranged two years ago, Professor W. H. JULIUS, of the University of Utrecht, has recently spent some weeks on Mt. Wilson. The prime object of his visit was to discuss the possible bearing of anomalous dispersion on astrophysical phenomena, in the hope that definite criteria might be found, capable of settling the question. A series of investigations has now been planned, covering both solar and laboratory work, and will be carried out as soon as possible.

While on Mt. Wilson Professor JULIUS employed the five-foot spectroheliograph to photograph the anomalous-dispersion phenomena of sodium vapor, which resemble the solar flocculi. This work, as well as the numerous discussions of the anomalous-dispersion theory, was a source of great pleasure and profit to all the members of the staff.

September, 1907. GEORGE E. HALE.

NEW APPOINTMENTS TO THE STAFF OF THE MT. WILSON SOLAR OBSERVATORY.

Professor J. C. KAPTEYN, of the University of Groningen, will hereafter spend several months of each year at Mt. Wilson, and take charge of such parallax and other similar work as may be done in connection with his "Plan of Selected Areas." So far as possible, the working programme of the 60-inch reflector will be arranged so that the photographs, both direct and spectroscopic, will be of service for Professor KAPTEYN's studies of stellar distribution, as well as for the prime purpose of the observatory—the investigation of stellar evolution. This can easily be done by giving preference to KAPTEYN's areas when undertaking general spectrographic surveys or in studying the smaller spiral nebulæ. In addition, certain nights will be set apart for his special purposes. The direct bearing, on the one hand, of KAPTEYN's important researches on the problem of stellar evolution, and the need, on the other, of a large reflector to furnish the data he desires for the fainter

stars, promise valuable returns from this co-operative undertaking. Professor KAPTEYN will commence work on Mt. Wilson as soon as the 60-inch reflector is ready for use, probably in the summer of 1908.

Dr. ARTHUR L. KING, of the University of California, will take charge of the physical laboratory of the Solar Observatory as soon as he can relinquish the duties of his present position, probably in January, 1908. It is proposed to undertake an extensive investigation of anomalous-dispersion phenomena, and the effects of temperature and pressure, for lines which will also be studied in sun-spots, at the center and limb of the Sun, in the chromosphere, and in stars of various types. Dr. KING will be assisted in the laboratory by Dr. OLMSTED, who has been engaged in similar work at Mt. Wilson during the past year.

GEORGE E. HALE.

September, 1907.

REQUEST FOR UNPUBLISHED OBSERVATIONS OF THE VARIABLE STAR *U GEMINORUM*.

Mr. J. VAN DER BILT, Astronomer at the observatory, Utrecht, Holland, has undertaken the definitive reduction of all available observations of this remarkable variable, and would be very glad to have copies of any unpublished observations, in such detail that they can be reduced by a normal photometric light-scale. They may be sent to him direct. Address Maliesingel 58, Utrecht; or if sent to the undersigned, they will be transmitted to him.

YERKES OBSERVATORY,
WILLIAMS BAY, WISCONSIN.

J. A. PARKHURST.

CHANGES IN THE STAFF OF LICK OBSERVATORY.

Mr. KEIVIN BURNS, Carnegie Assistant during the past four years, with duties in the measurement and reduction of stellar spectrograms, resigned, to take effect October 1st, in order to pursue postgraduate studies.

Dr. B. L. NEWKIRK, Carnegie Assistant during the past year, resigned, to take effect September 1st, to accept appointment as Assistant Professor of Mathematics and Mechanics in the College of Engineering, University of Minnesota.

HENRY C. PLUMMER, M. A., Assistant in the University of Oxford during the past six years, has been appointed a Fellow

in the Lick Observatory. His time will be devoted to work in the spectroscopic department.

Miss LEAH ALLEN, of Brown University, Providence, Rhode Island, has been appointed Carnegie Assistant with duties in the measurement and reduction of spectrograms.

MT. HAMILTON, September 23, 1907. W. W. CAMPBELL.

EPHEMERIDES FOR THE WATSON ASTEROIDS.

In accordance with the intention expressed in *Lick Observatory Bulletin* No. 114, to provide regularly ephemerides for coming oppositions of the various asteroids discovered by WATSON, as far as the progress made in determining their elements and first order perturbations by *Jupiter* may permit, ephemerides were computed by Miss GLANCY from the elements and perturbations derived under my direction in the Berkeley Astronomical Department, for the recent oppositions of (103) *Hera* and (179) *Klytæmnestra*. Unfortunately, these ephemerides were not completed in time for publication in a *Lick Observatory Bulletin*. A photographic position of *Hera* was secured, however, by Miss GLANCY, at this observatory on June 14th, and requests for observations of (179) were sent to Director CAMPBELL, of the Lick Observatory, and to Admiral WALKER, Superintendent of the United States Naval Observatory.

At the Lick Observatory three observations were secured by Mr. DUNCAN, on September 18th, 19th, and 20th, and Professor EICHELBERGER, of the Naval Observatory, has communicated to me a correction to the ephemeris of (179), based on an observation by Mr. HAMMOND, taken September 23d. In each case the ephemerides were given to 1^s and $0'.1$. The agreement between theory and observation is far better than was expected. The correction to the ephemeris of (103) on June 14th, is $+0^s.6$ and $-0'.3$. The correction to the ephemeris of (179), communicated by Professor EICHELBERGER for September 23d, is $+2^s$ and $-0'.1$. The mean correction, however, to the ephemeris of (179) from the Lick observations, September 19th, is 0^s and $-0'.1$.

The last opposition upon which the elements of (179) are based occurred eight years ago. A. O. LEUSCHNER.

BERKELEY ASTRONOMICAL DEPARTMENT, Oct. 2, 1907.

Courses in Astronomy.

The first term of the academic year 1907-1908 has opened with an increased enrollment in the courses in Practical Astronomy. There are now forty-six students engaged in night work. Of these twenty-two take the course 4B, especially intended for civil engineers; eight are enrolled in 4A, a course designed for students who have chosen astronomy for their profession; and sixteen in Astronomy 2, a general course offered to students as a culture study. Other enrollments during the current term are: General Astronomy, ninety-five; Least Squares, thirty-six; Interpolation, Numerical Integration, and Differentiation, six; Theoretical Astronomy (Graduate), three; Celestial Mechanics (Graduate), four. Of the graduate students, four are men and three women. In the undergraduate courses there is a notable increase this year in the percentage of men. The number of well-prepared, capable, and serious students in the various courses is also noteworthy. In view of the increased enrollment in the practical courses, the university has granted the department an additional assistant. Applications for the newly created position should be sent without delay to the Director of the Students' Observatory.

A. O. Leuschner.

Berkeley Astronomical Department, Oct. 2, 1907.

GENERAL NOTES.

Deaths.—During the last few months astronomy in central Europe has suffered a severe blow through the loss of four persons closely associated with the progress of the science in recent years. The *Astronomische Nachrichten,* No. 4190, contains three obituary notices. In the last number of these *Publications* brief mention was made of the death of Dr. EGON VON OPPOLZER, professor of astronomy at Innsbruck. Dr. OPPOLZER, son of the noted astronomer THEODORE VON OPPOLZER, author of the celebrated "Lehrbuch zur Bahnbestimmung der Kometen und Planeten," was born in Vienna on October 13, 1869, and died June 15, 1907, being therefore less than thirty-eight years of age. His education was obtained at the universities of Vienna and Munich. For a time he served as an assistant in the observatory at Prague, and in 1901 was made associate professor of astronomy at Innsbruck, and professor in 1906. Dr. OPPOLZER was an enthusiastic investigator, and made many contributions to the science of astronomy along various lines. He made investigations concerning the Earth's atmosphere and solar phenomena. He was also interested in photography and photometry, and will be remembered as the discoverer of the short-period variability in the brightness of the planet *Eros.* During the last few years Dr. v. OPPOLZER was engrossed in the building and equipping of a new observatory at Innsbruck, nearly the whole cost of which was paid out of his own pocket. The equipment was designed especially for work in spectroscopic and photographic lines, and was almost ready for use when the hand of death intervened to bring to a sudden close the life and work of an ardent searcher for truth.

On June 29th Professor SIEGFRIED CZARPSKI, Director of the Carl Zeiss firm, makers of the celebrated Zeiss lenses and optical instruments, died in Jena at the age of forty-six years. Although not an astronomer by profession, yet Dr. CZARPSKI, through his connection with the optical works and through attendance upon the meetings of the Astronomische Gesellschaft, came into contact with many of the astronomers of Europe. When a young man he was a student under HELMHOLZ, and through the recommendation of that master became

private assistant to Professor ABBE. The balance of his life was spent in Jena. Dr. CZARPSKI's chief contribution to science is a book on geometrical optics, called "Theorie der Optischen Instrumente nach ABBE."

On July 13th Dr. HEINRICH KREUTZ, associate professor of astronomy at the University of Kiel and editor of the *Astronomische Nachrichten,* passed away, after a long illness, at the age of fifty-two years. His preparation for the astronomical profession was obtained at the University of Bônn under the tutorship of SCHÖNFELD and KRUEGER. After further study in Vienna under WEISS and OPPOLZER, he became a computer in the Recheninstitut at Berlin. Dr. KREUTZ soon gave up this position, however, in order to accept the position of observer and computer at the Kiel Observatory when Professor KRUEGER was called there in 1883 to become director of the observatory and editor of the *Astronomische Nachrichten.* In this position KREUTZ became familiar with editorial work, and was naturally chosen to succeed KRUEGER in the editorship of the *Nachrichten* when the latter died, in 1896. The laborious duties of this position were performed with great care, and Professor KREUTZ succeeded in maintaining the high standard previously enjoyed by the *Nachrichten* as the leading astronomical journal of the world. Dr. KREUTZ was especially interested in the investigation of orbits of comets, and carried to completion several very extensive pieces of computation. The most important of these were investigations of the orbits of the comets 1843 I, 1861 II, 1880 I, 1882 II.

Another severe loss to astronomy came through the death on August 13th of Professor HERMANN CARL VOGEL, Director of the Astrophysical Observatory at Potsdam. Dr. VOGEL was the sixth Bruce medalist of the Astronomical Society of the Pacific, and reference to his life and work will be found on another page of this number of the *Publications.*

Notes from "Science."—MARY W. WHITNEY, professor of astronomy at Vassar College, and president of the Nantucket Maria Mitchell Association, spent a week lately at the Maria Mitchell Memorial on Nantucket, giving instructive talks to members and their guests on "Maria Mitchell" and on "Recent Discoveries in the Solar System." Professor WHITNEY has appointed a building committee to consider plans for an observ-

atory to house properly an equatorial telescope recently donated to the association. Already the sum of $2,138 has been subscribed, and the association in charge of the memorial hopes for subscriptions to enable it not only to house the telescope but also to equip the observatory so that it may be available for astronomical classes in the near future.

Sir David Gill's Address.—The presidential address of Sir DAVID GILL, delivered before the annual meeting of the British Association for the Advancement of Science at Leicester, has been printed in full in *Science* for August 16th. The address is highly interesting and instructive, and should be read by every one interested in astronomy.

Doctor's Degrees.—In *Science* for August 30th there is an article entitled "Doctorates Conferred by American Universities." During the last ten years the degree of Doctor of Philosophy and Doctor of Science (not including honorary degrees) has been conferred upon 2,715 persons, and of these 1,232 were taken in the sciences. Thirty-four degrees have been granted in astronomy, which stands ninth among the twenty sciences enumerated. Three doctorates in astronomy were conferred during the last academic year, as follows: By Columbia University, on ANNE SEWELL YOUNG, "The Stellar Clusters h and χ *Persei;* Measurement and Reduction of the Rutherford Photographs"; by the University of California, on JAMES DAVIS MADDRILL, "A Study of Several Stars of the δ *Cephei* Type"; by the University of Virginia, on FRANK WALKER REED, "Singular Points in the Approximate Development of the Perturbative Function."

NEW PUBLICATIONS.

AMBRONN, L. J., and R. Sternverzeichnis enthaltend alle Sterne bis zur 6.5tn Grösse für das Jahr 1900.0. Berlin: J. Springer. 1907. Large 8vo. x + 183 pp. Cloth.

CAMPBELL, W. W. A list of Lick Observatory negatives from which lantern-slides and transparencies can be supplied. Sacramento. 1907. 8vo. 21 pp. Paper.

COWLEY, ELIZABETH B., and WHITESIDE, IDA. Definitive orbit of Comet 1826 II. Kiel: Astronomische Abhandlungen als Ergänzungshefte zu den Astronomischen Nachrichten, Nr. 13. 1907. 4to. 18 pp. Paper.

DYSON, F. W. Determinations of wave-length from spectra obtained at the total solar eclipses of 1900, 1901, and 1905. London: Memoirs of the Royal Astronomical Society, appendix to Vol. LVII. 1906. 4to. 50 pp. Boards.

HUGGINS, Lady. Agnes Mary Clerke and Ellen Mary Clerke: An appreciation. London: Printed for private circulation. 1907. 8vo. 54 pp. Cloth.

LANGLEY, SAMUEL PIERPONT. Memorial meeting, December 3, 1906. Addresses by Doctor White, Professor Pickering, and Mr. Chanute. Washington; Smithsonian Miscellaneous Collections, No. 1720. 1907. 8vo. 49 pp. Paper.

PALISA, JOHANN. Katalog von 3,458 Sternen für das mittlere Aequinoktium 1875.0. Vienna. 1906. 4to. xii + 95 pp. Paper.

SCHORR, R. Tafel der Reductions-Konstanten zur Berechnung scheinbarer Sternörter für die Jahre 1850 bis 1860. Hamburg: Mitteilungen der Hamburger Sternwarte, Nr. 9. 1907. Large 8vo. viii + 230 pp. Paper.

SCHWARZSCHILD, K. Ueber die totale Sonnenfinsternis von 30 August, 1905. Göttingen: Astronomische Mitteilungen der K. Sternwarte zu Göttingen, 13 Teil. 1906. 4to. 73 pp. Plates. Paper.

TAYLOR, H. DENNIS. A system of applied optics. London: Macmillan & Company. 1906. Royal 8vo. 16 + 334 pp. Cloth.

Vogel, H. C. Die zwei Doppelrefraktoren des Observatoriums. Potsdam: Publikationen des Astrophysikalischen Observatoriums zu Potsdam. Band 15, erstes Stück. 1907. 4to. 59 pp. Plates. Paper.

Berliner Astronomisches Jahrbuch für 1909. Berlin: Ferd. Dümmler. 1907. 8vo. x + 615 pp. Paper.

Connaisance des temps, pour l'an 1909. Paris: Gauthier-Villars. 1907. 8vo. viii + 931 pp. Paper. 4 francs.

Memoire del R. Osservatorio Astronomico al Collejio Romano. Series III, Vol. IV, Parte II. Rome: 1907. 4to. 285 pp. Paper.

Proceedings (The) of the optical convention, No. I. London. 1905. London: Norgate and Williams. Royal 8vo. vi + 247 pp. Cloth, 10 s.

Publications of the Lick Observatory.[1] Volume IX, Parts 1, 2, and 3. Sacramento. 1907. 4to. 70 pp. Paper.

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[1] See note on page 241.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD AT THE LICK OBSERVATORY, MT. HAMILTON, ON SEPTEMBER 14, 1907, AT 8 P.M.

President CUSHING presided. The following directors were present: AITKEN, CAMPBELL, CRAWFORD, CUSHING, RICHARDSON, TOWNLEY, and ZIEL. The minutes of the last meeting (July 13, 1907) were approved.

The Librarian reported many more generous responses to the circular letter concerning the library.

A reply, acknowledging with thanks the receipt of the award of the Donohoe comet-medal, from Professor H. THIELE was read.

The Library Committee was authorized to procure a card-catalogue case and an accessions-book.

On behalf of the Committee on the Donohoe Comet-Medal Professor CAMPBELL, chairman, reported the following awards:—

To GIACOBINI for the discovery of Comet *a* 1907; to MELLISH for the discovery of Comet *b* 1907; to GIACOBINI for the discovery of Comet *c* 1907; to DANIEL for the discovery of Comet *d* 1907.

The resignation of Dr. NEWKIRK from the Publication Committee was accepted with regret.

Dr. JAMES D. MADDRILL was elected to fill the vacancy on the Publication Committee, *vice* NEWKIRK resigned.

The Committee on Meetings, consisting of Messrs. CAMPBELL, LEUSCHNER, and TOWNLEY, was continued, and requested to report at the next meeting.

The following was elected to membership:—

B. L. HODGHEAD, 601 Merchants Exchange, San Francisco.

The following was elected an institutional member:—

Library of University of Washington, Seattle, Wash.

The following were elected corresponding members:—

Library of Solar Observatory, Mt. Wilson, Cal.

Flower Observatory, University of Pennsylvania, Upper Derby, Pa.

The following resolution was introduced and passed unanimously:—

Resolved, That the bonds belonging to this Society be deposited in trust with the Mercantile Trust Company of San Francisco, a corporation, the said Trust Company to collect the interest and pay the same as it accrues to the Treasurer of this Society, the said bonds to be delivered by said Trust Company only as directed by this Society, the intention of the Society to remove the same from the custody of said Trust Company to be evidenced by a resolution of the Board of Directors, under seal of this corporation, and duly certified by the President, or a Vice-President, and the Secretary of the Society.

Be it further Resolved, That the President and Treasurer of this Society are hereby authorized to take all necessary steps to carry this resolution into full force and effect, including, if necessary, the indorsement by them of any of the bonds belonging to this Society.

A vote of thanks to the Director and Staff of the Lick Observatory for their invitation and hospitality at this meeting was passed unanimously.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. Chas. S. Cushing .... *President*
Mr. A. H. Babcock .... *First Vice-President*
Mr. W. W. Campbell .... *Second Vice-President*
Mr. Geo E. Hale .... *Third Vice-President*
Mr. R. T. Crawford (Students' Observatory, Berkeley) .... *Secretary*
Mr. R. G. Aitken (Mount Hamilton, Cal.) .... *Secretary*
Mr. F. R. Ziel .... *Treasurer*

Board of Directors—Messrs. Aitken, Babcock, Burckhalter, Campbell, Crocker, Crawford, Cushing, Hale, Richardson, Townley, Ziel.

Finance Committee—Messrs. Richardson, Crocker, Burckhalter.

Committee on Publication—Messrs. Aitken, Townley, Maddrill.

Library Committee—Messrs. Crawford, Irving, Townley.

Committee on the Comet-Medal — Messrs. Campbell (ex-officio), Burckhalter, Perrine.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, Students' Observatory, Berkeley.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., Students' Observatory, Berkeley, Cal., who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," Students' Observatory, Berkeley, Cal., in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)

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COMMITTEE ON PUBLICATION.

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Sidney D. Townley, Palo Alto, Cal.

James D. Maddrill, Ukiah, Cal.

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XIX. SAN FRANCISCO, CALIFORNIA, DECEMBER 10, 1907. No. 117.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1908.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

New Moon	Jan. 3,	$1^h 43^m$	P.M.	New Moon	Feb. 2,	$12^h 36^m$	A.M.
First Quarter	" 10,	5 53	A.M.	First Quarter	" 8,	8 27	P.M.
Full Moon	" 18,	5 37	A.M.	Full Moon	" 17,	1 5	A.M.
Last Quarter	" 26,	7 1	A.M.	Last Quarter	" 24,	7 24	P.M.

The first of the three solar eclipses of the year will occur on January 3d. It will be a total eclipse, the line of totality running through the Pacific Ocean from a point north of Australia to the east coast of Central America. It will be seen as a partial eclipse from points in the central and southern parts of the United States late in the afternoon. The path of totality is mainly over the open ocean, but it crosses several of the small islands in the South Pacific, which afford fairly good observing stations. Some of these will be made use of by observing parties from the Lick and other observatories. The maximum duration of totality is a little more than four minutes; this is rather more than the average duration. One circumstance is perhaps worth noting. As the line of the eclipse track crosses the line "where the day begins," the local time of beginning is sunrise of January 4th, and the local time of ending is sunset on January 3d.

The Earth is in perihelion on the morning of January 2d.

Mercury is a morning star at the beginning of the year, too near the Sun for naked-eye observations, as it rises only half an hour before sunrise. It passes superior conjunction on the evening of January 13th, reaches greatest east elongation on February 13th, and comes to inferior conjunction on February

28th. At the time of greatest elongation it remains above the horizon rather more than an hour and a half after sunset, and it will be an easy object for naked-eye view on a clear evening during the late twilight. The interval between the setting of the Sun and of the planet is more than an hour during the period from two weeks before to about one week after the date of greatest elongation. The duration of visibility and maximum elongation from the Sun are both much less than the average for winter east elongations, for the reason that the planet passes its perihelion less than a day after the time of greatest elongation. There will be a much better opportunity for seeing the planet in June.

Venus is an evening star, gradually increasing its distance from the Sun from 29°, on January 1st, to 36°, on February 29th. On the first-named date it sets a trifle more than two hours after sunset, and this interval increases to more than three hours by the end of February. On the evening of February 13th it will be within one degree of the point in the sky known as the vernal equinox. It passes *Saturn* about noon on February 10th, a little more than one degree, or two apparent diameters of the Moon, north of the latter.

Mars will not be in good position for observation throughout the year on account of its distance from us and consequent faintness, although it will not be difficult to see it except for a month or two about the middle of the year, while it is near conjunction with the Sun. On January 1st it is an evening star, and remains above the horizon until nearly 11 o'clock, and by the end of February it sets a little before $10^h\ 30^m$. During the two-months period it moves about 38° eastward and 17° northward through the constellation *Pisces* into *Aries*, passing a little north of the vernal equinox on January 10th. On January 1st its distance from the Sun will be 127 millions of miles. This is more than three times as great as the distance at the time of opposition in July, 1907, and its brightness will be not one tenth as great as it was then; but it will still be as bright as all but the brightest stars, and there is no star as bright in near proximity to the planet, although it is quite close to *Saturn* on January 1st. So there will be no difficulty in identifying it. Its distance from the Earth is increasing rapidly, and it will lose more than half its brightness by the end of February.

Jupiter is in fine position for observation, as it comes to opposition with the Sun on January 29th. It will then be above the horizon throughout the whole night, and during the whole two-months period it will be in sight whenever the twilight is sufficiently dark to show it. It is in the constellation *Cancer,* not very near any bright star, and retrogrades, moves westward, about 10°, and 2° northward by February 29th.

Saturn is an evening star, setting a little after $10^h\ 30^m$ on January 1st, and a little after 7^h on February 29th. At the beginning of January it is near *Mars,* about 2° south, but its slower motion among the stars makes the distance between the planets increase rapidly, and by the end of February it is more than 30°. The very interesting series of appearances and disappearances of the rings which has been going on during 1907 ceases early in January. On January 1st the Earth and Sun are on opposite sides of the plane of the rings, but in a few days the Earth passes to the other side of the plane, and for the following fourteen or fifteen years Earth and Sun will both be on the southern side. For some months the rings will present the appearance of a very narrow streak, but in the summer of 1908 the apparent minor axis will be about one eighth of the major.

Uranus is in conjunction with the Sun on January 4th and becomes a morning star, but does not get far enough away for visibility until after the end of the period. It is so faint —just within the limit of naked-eye visibility—that it cannot be seen without a telescope at a much lower altitude than 25°.

Neptune is in opposition with the Sun on January 4th, and is therefore above the horizon throughout the whole night at that time, but it is too faint for naked-eye observation. It is in the constellation *Gemini.*

NOTICES TO MEMBERS.

The next number of our Publications is to contain the new membership list. The Committee on Publication requests the members to notify the Secretary of any changes of address from those given in Publications No. 112.

* * *

The library has at its disposal a fund made up of contributions sent in response to the Society's circular letter asking for help in building up a new library. This money is to be expended for the purchase of books of a popular nature. In order that we may get such books as the members of the Society desire, the Librarian hereby requests them to send to him suggestive lists of books. The only books of a popular nature at present in our library are:—

CLERKE. Problems in Astrophysics.
CLERKE. The System of the Stars.
HOVESTADT. Jena Glass.
HOWE. Elements of Descriptive Astronomy.
HUGGINS. The Royal Society.
IRVING. How to Know the Starry Heavens.
LANGLEY. The New Astronomy.
WEBB. Celestial Objects for Common Telescopes.
YOUNG. General Astronomy.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Orbit of the Spectroscopic Binary θ *Draconis*.[1]

The binary nature of this star was discovered by Director Campbell and announced in 1899. In the interval from March, 1898, to July, 1904, thirty-two plates were secured that could be used to measure the radial velocity of the star. These were all measured by the writer at Mt. Hamilton, and from the results preliminary elements were computed graphically by the formulæ of Lehmann-Filhés. These elements were corrected differentially by a least-squares solution which gave the following set of final elements:—

$$\begin{aligned} \text{Period} &= 3.0708 \quad \pm 0.000032 \text{ days} \\ e &= 0.0141 \quad \pm 0.0166 \\ T &= \text{J. D. } 2415368.962 \quad \pm 0.499 \text{ days} \\ \omega &= 126^\circ.112 \quad \pm 58^\circ.6 \\ k &= 23.47 \quad \pm 0.324 \\ \text{Velocity of system} &= -8.36^{\text{km}} \quad \pm 0.30^{\text{km}} \\ a \sin i &= 9{,}900{,}000^{\text{km}}. \end{aligned}$$

Santiago, Chile, June, 1907. Heber D. Curtis.

The Orbits of the Spectroscopic Binaries α *Carinæ*, κ *Velorum*, and α *Pavonis*.

The binary character of α *Carinæ* and κ *Velorum* was detected by Professor W. H. Wright in the course of the work of the D. O. Mills Expedition to the Southern Hemisphere. The binary character of α *Pavonis* was also suspected by him from preliminary measures of the first four plates taken, and was independently discovered from the definitive reductions of the same plates by Dr. S. Albrecht.

The three stars are of the same general spectral type described as Type B 3 A in the Harvard classification. In

[1] The details of this orbit are published in *Lick Observatory Bulletin*, No. 122.

the part of the spectrum covered by the spectroscope of the Mills reflector, only six lines are measurable. It is the opinion of the writer that the application of the method of least squares to stars of this type of spectrum and number of lines is not warranted except in the case that a large number of observations are available, extending over a long interval of time. Preliminary elements were therefore first derived graphically by the formulæ of LEHMANN-FILHÉS. Changes were then made in the derived elements, after comparing with the curve given by the observations, and several sets of elements tested by the observation values. With some experience in this method it is possible in a relatively short time to test and change the elements given by the graphical solution until the resulting values would be little if any bettered by a least-squares solution.

By such methods the following sets of elements were derived:—

	a Carinæ.	*κ Velorum.*	*a Pavonis.*
Period =	6.744 days	116.65 days	11.753 days
$e =$	0.18	0.19	0.01
$k =$	21.5	46.5	7.25
$T =$	J. D. 2416533.81	2416459.00	2416379.90
$\omega =$	115°.84	96°.23	224°.80
Velocity of system =	$+ 23.3^{km}$	$+ 21.9^{km}$	$+ 2.0^{km}$
$a \sin i =$	$1,960,000^{km}$	$73,200,000^{km}$	$1,170,000^{km}$

Details of the observations and residuals are given in *Lick Observatory Bulletin*, No. 122.

HEBER D. CURTIS.

THE D. O. MILLS EXPEDITION,
SANTIAGO, CHILE, June, 1907.

NOTE ON COMET *c* 1907 (MELLISH).

Comet *c* 1907 was discovered on the morning of October 14th by JOHN E. MELLISH, of Cottage Grove (near Madison), Wisconsin, in R. A. 8^h 31^m, Decl. $-9°$ $24'$. It was visible with an opera-glass.

From the first three available observations (October 15th, by HARTWIG, at Bamberg; October 16th, 17th, by DUNCAN, at Mt. Hamilton) a preliminary orbit was computed by Professor CRAWFORD, Miss GLANCY, and Miss MORGAN. The elements and an ephemeris are given in *Lick Observatory Bulletin*, No. 121.

On the basis of observations giving a longer arc (October 15th, by HARTWIG, at Bamberg; October 19th, 30th, by DUNCAN, at Mt. Hamilton) a second orbit was computed by Professor CRAWFORD and Miss GLANCY. A part of this computation was checked by Miss MORGAN. The elements and ephemeris extending to the end of this year are published in *Lick Observatory Bulletin*, No. 124.

The two orbits (both parabolic) differ very little from each other. The longitude of the node is 55°; the longitude of the perihelion is 350°. The motion in the orbit is retrograde, the inclination of the orbit plane to the ecliptic being 120°. The comet passed perihelion on September 14th, at a distance of 91,000,000 miles from the Sun. It was nearest to the Earth on November 11th, and at that time was distant 38,000,000 miles, having a theoretical brightness three times as great as on the day of discovery. The comet is now receding from both the Sun and the Earth. It is a matter of interest that the observed brightness of the comet to date has not agreed with the computed brightness.

A. O. LEUSCHNER.

BERKELEY ASTRONOMICAL DEPARTMENT, November 20, 1907.

ECLIPSE EXPEDITION.

The Lick Observatory Crocker Eclipse Expedition left Mt. Hamilton on November 18th, and sailed from San Francisco for Tahiti on the steamship Mariposa on November 22d. From Tahiti the party is to be conveyed to Flint Island, about four hundred miles north, by means of a U. S. naval vessel. It is expected that the party will arrive at Flint Island about December 5th, which will allow four weeks in which to erect the instruments and to make the necessary preparations for the event. Flint Island lies at about 12° south latitude, and is several miles south of the central line of the eclipse shadow. The eclipse is to occur at about $11^h\ 18^m$, local mean time, and totality will last about four minutes.

The party consists of Director CAMPBELL, Astronomers PERRINE and AITKEN, and Assistant ALBRECHT of the Lick Observatory, and Professor E. P. LEWIS of the University of California. They expect to again reach San Francisco about January 25th.

SIDNEY D. TOWNLEY.

Mr. W. F. MEYER, a graduate of Drake University, has been appointed assistant in astronomy in the Berkeley Astronomical Department of the University of California.

NOTE ON COMET *a* 1907 (GIACOBINI).

A telegram has just been received stating that WOLF observed this comet on December $4^d.4364$ Gr. M. T., in right ascension $3^h\ 23^m\ 40^s$ and declination $+50°\ 35'$. This place is represented very closely by the orbit computed by Mr. EINARSON, Miss GLANCY, and Miss JOY, from observations extending from March 9th to April 9th. This orbit was published in *Lick Observatory Bulletin*, No. 113. The residuals in α and δ for the above position are (O–C) $+13^s$ and $-3'$ respectively.

RUSSELL TRACY CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT, December 7, 1907.

GENERAL NOTES.

On the Constancy of Wave-Length of Spectral Lines.—The October number of the *Astrophysical Journal* contains a translation of a recent article by Professor KAYSER, in which he disposes of the question of the supposed variability of wavelength with variation of circumstances. The following sentences are extracts: "An extensive literature has already grown up on the question whether the wave-lengths of spectral lines are invariable or whether they depend on the mode of production of the spectrum, whether the density of the vapor has any effect, etc. . . . The importance of this question in terrestrial and astronomical spectroscopy leads me to make some remarks on the subject. . . . I am convinced that the differences which different observers obtain for the same line are due to the fact that they start from different standards which do not agree with each other. . . . The fact that with the same standards an accuracy of a few thousandths of an Ångstrom unit is attained, while with different standards only as many hundredths of a unit, led the International Solar Union to place upon its programme the more precise determination of the standards as one of the most pressing problems. . . . At the meeting of the Union in Paris in May, Professor AMES was able to communicate the fact that Dr. PFUND had made experiments in his laboratory with the interferometer, which proved that the wave-lengths are precisely the same, regardless of whether the spectrum was produced in the spark or in the arc, at atmospheric pressure or in a vacuum, of pure metals or of an alloy or salts. This was true without exception for all the elements investigated. Professor FABRY declared that his experiments had yielded precisely the same result. Inasmuch as the most precise method which we have was employed here, we must regard these experiments as decisive, and consider that the question of the constancy of the wave-lengths is finally settled."

Notes from "Science."—A. N. SKINNER, professor of mathematics, U. S. N., of the U. S. Naval Observatory, was retired according to law upon reaching the age of sixty-two years, on

August 12, 1907. Professor SKINNER will remain upon active duty, however, until the completion of some unfinished work on the Astronomische Gesellschaft zone — 14° to — 18°, which was observed under his direction from 1892 to 1894. H. L. RICE, formerly assistant astronomer at the observatory, has been appointed to the professorship vacated by this retirement, and H. R. MORGAN succeeds Mr. RICE in the position of assistant astronomer. The organization of the work of the observatory has been changed in the direction of the consolidation of the work, and Professor W. S. EICHELBERGER, U. S. N., has been placed in charge of all the astronomical work of the observatory.

The Committee of the French Academy of Sciences having scientific control of the French geodetic operations on the equator has reported the completion of the remeasurement of the historic arc in Peru.

M. MAURICE LOEWY, director of the Paris Observatory, born in Vienna in 1833, died on October 15th, while attending a meeting of the national board of French observatories of the Ministry of Public Instruction.

Dr. RALPH H. CURTISS, formerly of the Lick and more recently of the Allegheny Observatory, has been appointed assistant professor of astrophysics in the University of Michigan.

Asaph Hall.—The death is announced of ASAPH HALL, professor of mathematics U. S. N. (retired). Professor HALL was born at Goshen, Conn., October 15, 1829. The early years of his manhood were devoted to teaching school, and it was not until he had reached the mature age of twenty-eight years that his astronomical career was begun as student and assistant at Harvard College Observatory. He entered the Naval Observatory in 1862, and remained in continuous connection with that institution until his retirement in 1891. Professor HALL had the use of the 26-inch refractor at the Naval Observatory, which, at the time it was completed, was the largest refractor in the world. His attention was given chiefly to the measurement of double stars and the satellites of the solar system. Professor HALL also investigated the orbits of several of the satellites, but his name will be longest remembered as the discoverer of the two tiny moons of *Mars*.

Dr. ELIS STRÖMGREN, Privatdozent in the University of Kiel, has been appointed professor and Director of the observatory in Copenhagen, in the place of Professor T. N. THIELE, who has retired.

NEW PUBLICATIONS.

COOKSON, BRYAN. Determination of the elements of the orbits of *Jupiter's* satellites from photographs taken at the Cape in 1902. Edinburgh. 1907. 4to; 122 pp. Paper. 3s.

DUNÉR, N. C. Ueber die Rotation der Sonne, zweite Abhandlungen. Upsala: Akademische Buchhandlung. 1907. 4to; 64 pp. Paper.

HEDRICK, H. B. Catalogue of zodiacal stars for 1900 and 1920 reduced to an absolute system. Astronomical papers prepared for the use of the American Ephemeris and Nautical Almanac, Vol. VIII, Part III. Washington: Bureau of Equipment, Navy Department. 1905. 4to; 190 pp. Paper.

KAMENSKIJ et E. KOROLIKOV. Les éléments approchés et l'éphéméride de la comète d'Encke. Bulletin de l'Académie Impériale des Sciences. St. Petersburg. 1907. Large 8vo; 8 pp. Paper.

A catalogue of 420 standard stars mostly between 31° and 41° south declination for the equinox 1905.0, from observations made at the Perth Observatory, Western Australia, under the direction of W. ERNEST COOKE. Perth. 1907. 4to; 13 pp. Cloth.

Astronomical and magnetical and meteorological observations made at the Royal Observatory, Greenwich, in the year 1905. Edinburgh. 1907. 4to. Cloth.

Etude de l'atmosphère. Observatoire Constantin. Fascicule II. St. Petersburg. 1906. 4to; ix + 45 + 92 pp. Paper.

Minutes of the Meeting of the Board of Directors, Held in Room 601, Merchants Exchange, San Francisco, Cal., on November 30, 1907, at 2 p. m.

The following directors were present: Burckhalter, Crawford, Cushing, Richardson, Townley, Ziel. Directors Aitken, Babcock, Campbell, and Hale were represented by proxies.

President Cushing presided. The minutes of the meeting of September 14, 1907, were changed by substituting "corresponding institutions" for "corresponding members," and then approved.

The Bruce Medal for 1907 was awarded.

The following were elected to membership:—

Dr. Thos. Porter, 1111 Washington Street, Oakland, Cal. (temporary address).

Mr. Morgan Sanders, 1419 West Lanvale Street, Baltimore, Md.

The following was elected an institutional member:—

Public Library, Seattle, Wash.

It was moved, seconded, and carried, that the temporary publication address of the Society be 601 Merchants Exchange, San Francisco, Cal.

The Librarian reported briefly upon the present state of the Library.

Adjourned.

Minutes of the Meeting of the Society, Held in Room 601, Merchants Exchange, San Francisco, Cal., on November 30, 1907, at 2:30 p. m.

President Cushing presided. Upon calling the Society to order he announced that the meeting would be devoted to informal discussion of current astronomical problems.

Professor Leuschner gave a brief history and an account of the present state of the work on the Watson asteroids, which has been carried on at Berkeley for the last seven years.

Professor Townley made a few remarks on astronomical work at Stanford University, and also gave a brief account of the more recent work on the variation of latitude.

Mr. Burckhalter called attention to some recent observations of an unusual character that he had made upon the rings of *Saturn*.

A general discussion was had upon Professor Lowell's article on *Mars* in the December (1907) *Century*.

Adjourned.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the calendar year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our bookkeeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, Students' Observatory, Berkeley.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., Students' Observatory, Berkeley, Cal., who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding date of publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific," Students' Observatory, Berkeley, Cal., in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.

(February, April, June, August, October, December.)

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